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THE OPEN PAN SYSTEM

OF

WHITE SUGAR MANUFACTURE

BY

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Errata to the Scientific Monography No. 3 of the Imperial Council of Agricultural Research, entitled "The Open Pan System of White Sugar Manufacture."

Page 14, paragraph 1, line 2, *for* "eane" *read* "cane".

Page 18, fifth line below Table IX, *for* "full" *read* "fuel".

Page 47, lines 8—9, *for* "defectants" *read* "defecants".

Page 53, paragraph 2, section (*b*)
Juice Boiling, ... *for* "(boiling foreman) (on contract)" *read* "(boiling foreman on contract)".

Page 76, line 20, *instead of* the formula for available sucrose per cent. "$100 \times \frac{(jm)}{(s-m)}$" *read* "$100 \times \frac{s(j-m)}{j(s-m)}$"

Page 91, paragraph 3, line 2, *instead of* "the object the finding out" *read* "the object of finding out".

Page 94, line 3 from bottom, *for* "barbon" *read* "carbon".

Page 101, Table L, No. 6, *for* "Sen-dried" *read* "Sun-dried".

Page 107, line 11 from bottom, *for* "distribution" *read* "distributed".

Page 109, Table LV, A. *Bhopal Process*, No. 5, *for* "pottod" *read* "potted".

Page 111, paragraph 2, line 3, *for* "pro-" *read* "prov-".

Page 131, line 8, *for* "Process" *read* "Processes".

Page 141, line 2, from bottom, *for* "ap." *read* "sp."

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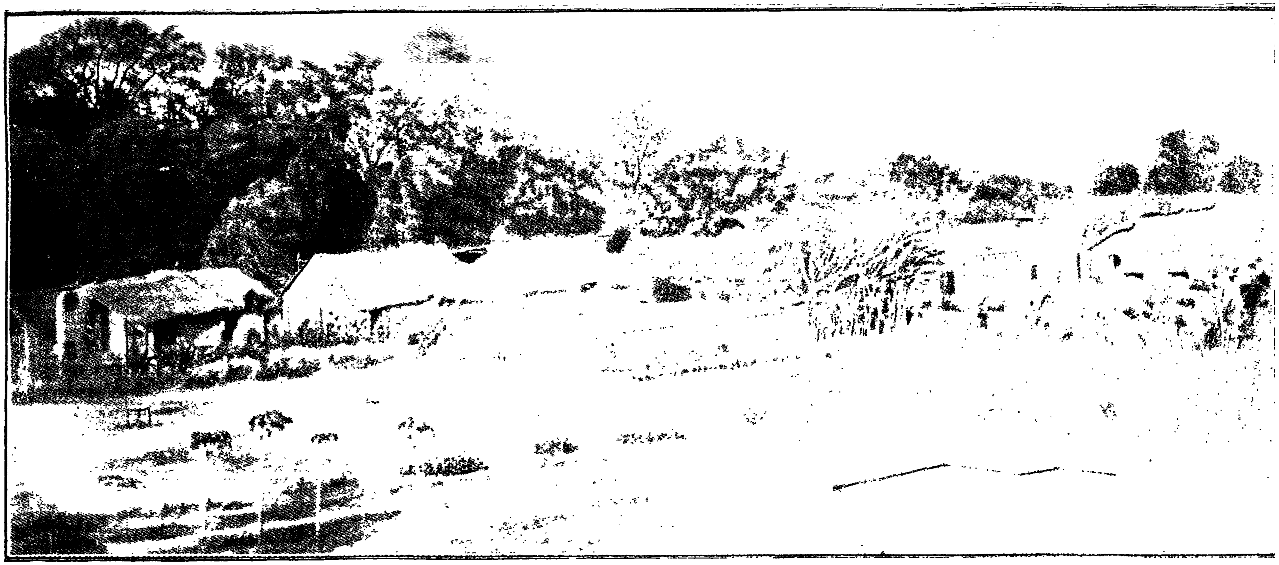
PLATE I.



General view of the Nagalia Farm buildings, Bilari, where the experiments were conducted.

INTRODUCTION.

The manufacture of sugar by the indigenous process is well-known to be wasteful. In other parts of the world where similar processes were employed in the past (*e.g.*, the "Caua" factories of the Philippine Islands and the "Copper-wall" factories of the British West Indian Islands), they have all had to give place, under the stress of competition, to the modern factory system. One may well ask, therefore, why a process which is admittedly wasteful and which has gradually disappeared from other sugar-producing countries of the world, should be encouraged in this country. To give a satisfactory answer to this question, one has to refer, on the one hand, to the size and importance of the indigenous industry *vis-a-vis* the Indian factory industry, and on the other hand, to its importance to the general agricultural system of the country.

As regards the size of the indigenous industry, the Tariff Board gives* the following figures for the manner in which the total production of 35·2 million tons of cane in India in 1927-28 was utilised:—

	Tons.
For sets	700,000
For chewing	4,500,000
For direct manufacture of white sugar . .	750,000
For manufacture of white sugar by *bel* process .	3,800,000
For manufacture of *gur*	25,450,000
TOTAL .	35,200,000

These figures show that the *Bel* process accounts for over five times the quantity of cane used for the manufacture of white sugar in factories. It is estimated that the present production of sugar by the *Bel* process is over 200,000 tons per year, whilst the total output of the Indian factories is only about 120,000 tons annually. In point of size, therefore, the Khandsari industry is of considerable importance.

It is of still greater importance in relation to the agricultural system particularly of the United Provinces and, possibly, in the near future, of the Punjab. The Khandsaris being small-scale concerns are able to operate in the large areas in the interior where lack of communication or scattered cultivation make the establishment of central factories impossible at present. If the Khandsari industry were to disappear, cane cultivation will become greatly restricted and the installation of central factories later on will be much more difficult.

* See "The Report of the Indian Tariff Board on the Sugar Industry", 1931, page 44.

Furthermore, the cost of production by the Khandsaris is not high. As the Tariff Board points out* "Overhead Charges are low and the cost of supervision negligible, and this to a considerable extent makes good the loss incurred by low extraction. Capital cost is estimated at 6·79 annas per maund of cane crushed as against Re. 1 per maund of cane crushed in Centrals".

Appreciating the importance of the Khandsari industry and realising that it will in any case be a long time before the factory industry of this country will have developed sufficiently to displace the indigenous and the imported sugar, the Imperial Council of Agricultural Research took up the question of improving the industry.

Through the courtesy and kind co-operation of the Bhopal Durbar and the ready assistance of their Director of Agriculture, Khan Bahadur S. M. Hadi, a preliminary test was conducted there by Mr. P. B. Sanyal on the "Bhopal" *bel*, designed by Mr. Hadi and described in his book "The Indian Sugar Industry"† (1929). The results are summarized in Part I of this Report. It was then decided that arrangements should be made for a practical test extending over a full season and conducted under actual commercial conditions, a Bhopal *bel* ‡ and a Rohilkhand *bel* being worked side by side and proper chemical control being maintained. This commercial test, which forms the subject matter of Part II of the present report, was conducted from 20th January 1931 to 24th April 1931 at the Shanker Agricultural Farm, Nagalia (Bilari, District Moradabad, U. P.), owned by Mr. Har Sahai Gupta.

The commendable interest taken by the Bhopal Durbar in the trial and introduction into the State of methods of sugar manufacture suitable for small scale working deserves special mention here. Grateful acknowledgment is also made of the facilities provided by the Durbar for carrying out the tests described in Part I of this Report.

The Bilari experiments were under the charge of Mr. Gupta in whose name the grant from the Imperial Council of Agricultural Research was sanctioned. The writer was in technical control of the work. Mr. Hadi with a large staff, voluntarily came to Bilari at considerable inconvenience to himself and personally supervised the work throughout. The writer desires to express his gratitude to both these gentlemen for the whole-hearted co-operation which he received from them. Thanks are also due to the Director, The Imperial Institute of Agricultural Research, Pusa, for the

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* Report of the Indian Tariff Board on the Indian Sugar Industry, p. 51.

† "The Indian Sugar Industry" by Khan Bahadur S. M. Hadi, 1929.

‡ "Bhopal" *bel* and "Bhopal" process are the names given by Mr. Hadi to the plant and process experimented with by him at Bhopal. This nomenclature has been accepted by the author as it serves to distinguish the plant and process now tested from those evolved by Mr. Hadi earlier in his career and described in his publications from time to time.

loan of apparatus and the services of Messrs. P. B. Sanyal and S. Das, two Chemists of the Pusa staff. Messrs. Sanyal and Das, who were in charge of the chemical control, and Mr. Sibte Safdar, who looked after the manufacturing operations, deserve thanks for the conscientious manner in which they discharged their duties. The writer is also indebted to Messrs. A. R. Khan, R. N. Johry and Abrar Hussain of the H. B. Technological Institute, Cawnpore, for assistance in connection with the special tests at Bilari and in calculating several of the tables,

THE OPEN PAN SYSTEM OF WHITE SUGAR MANUFACTURE.

Report of experiments conducted under the auspices of The Imperial Council of Agricultural Research, India.

PART I.

The Bhopal experiments.*

CHAPTER I.

Sugar making tests.

Limitations under which the tests were carried out. Before proceeding to describe and discuss the Bhopal experiments, it is necessary to state the limitations under which these tests were carried out. It was not possible to carry out the full commercial test which the Sugar Committee had in view, owing to the restricted amount of cane available. Only two days' full scale working was possible and even for those days the manufacture of second sugar from molasses could not be completed. In addition to the two full days' tests, experimental boilings were conducted with juices from different varieties of cane. These tests extended over nine days (so far as the boiling of first *rab* was concerned) and the quantities of juice handled daily varied from one-eighth to three-eighths of the full capacity of the boiling plant. In consequence of these unfavourable circumstances, the report which follows is largely an analysis of different parts of the process rather than a test of the process as a whole.

Plant and process employed. A detailed description of the plant and process employed under the Bhopal system is given in a subsequent section in connection with the Bilari experiments. Only a brief outline is, therefore, given below of the plant and process used at Bhopal. For crushing the cane, bullock mills were mostly employed, excepting when large-scale tests were made when a power-driven mill was used. The bullock mills used were of the following types:—

(*a*) Chattanooga Mill No. 12 (sold by the Saran Engineering Co., Ltd., Cawnpore),

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*These experiments were carried out by Mr. P. B. Sanyal, M.Sc., before the author's appointment as Sugar Technologist to the Imperial Council of Agricultural Research.

(*b*) Hathi Mill (made by Burn & Co., Ltd., Calcutta),
(*c*) Mill (made by Marshall Sons & Co., Ltd., Bombay),
(*d*) Kisan Mill (made by Kirloskar Bros., Kirloskarvadi, District Satara),
(*e*) Mill made locally by Haji Musa.

For boiling the juice various *bels* of Bhopal type were used. For a description of these, reference may be made to Mr. Hadi's book "The Indian Sugar Industry". The Bhopal *bel* consists essentially of a number of small pans placed in series on a long flue, the arrangement having the double object of (*a*) raising the juice quickly to boiling point and of speeding up boiling so as to reduce inversion, and (*b*) of reducing charring and caramelization. The strike is not effected by ladling out syrup which has reached the concentration for crystallization, as in the Rohilkhand *bel* but by the removal of the last pan from the fire, this being made possible by the use of an auxiliary *bel* consisting of one flat-bottomed galvanized iron pan and two round-bottomed iron pans. The syrup is transferred to the latter *bel* at a lower concentration than pertains in the finishing pan of the Rohilkhand *bel*, and caramelization is considerably reduced. The method of clarification is similar to that followed in Rohilkhand. In making first *rab* (that is, Massecuite from juice), the mucilagenous infusion of *Deola* (*Hibiscus ficulneus*) *or of Bhindi* (*Hibiscus esculentus*) is used, a solution of *sajji* (crude sodium carbonate) being added for partially neutralizing the acidity of the juice. If dark coloured juices are met with, sodium hydrosulphite is used as a bleaching agent. The boiling of second *rab* from the first molasses is carried out in the auxiliary *bel*, lime water is used for clarifying and sodium hydrosulphite for decolourising in the finishing pan.

On removal from the finishing pan, the *rab* is run into earthenware pans fixed in the ground. Portions of the *rab* are taken out and poured back from a height, the rapid cooling that results producing crystallization. After the desired amount of crystal formation has taken place, the *rab* is filled into empty kerosene oil tins (each of about four gallons capacity) which are stored for seven to ten days in the case of first *rab* and ten to fifteen days for second *rab*. At the end of this period crystallization is complete. The tins are then emptied into a shallow trough or pan for breaking lumps of *rab* (or the operation is conducted in a pugmill worked by hand). The pugged *rab* is machined in centrifugal machines, the particular machine used having a bracket of 18 inches diameter and run by a separate $2\frac{3}{4}$ H. P. oil-engine giving a basket speed of 1,800 to 2,100 R. P. M. The sugar is washed with hot water containing a little stannous chloride. The molasses obtained from the first *rab* is mixed with wash water (from the centrifugals, pugmill and empty tins in which *rab* was stored) till its density is 68°—70° Brix. The dilute molasses is boiled for making second *rab*. The wet sugar obtained from the centrifugal machine is dried in the sun, lumps being broken by crushing with a wooden hand-roller against a board. The rolling breaks

up the crystals (without completely powdering them) and the sunlight bleaches the sugar and in the end a finished sugar of moderate whiteness is obtained.

Nature of experimental work done at Bhopal. The experimental work done at Bhopal consisted of—

(*a*) Tests with full day's supply of juice. These were conducted on only two days. The chemical control on these days was not as comprehensive as on the days when small-scale tests were made.

(*b*) Small-scale tests. Small quantities of canes of different varieties were crushed and the juice worked up into *rab*. All weights were carefully determined and accurate chemical control was maintained. Although the tests were not on a commercial scale, they have nevertheless provided useful data regarding this method of sugar manufacture. Incidentally they constitute a comparative study of the sugar manufacturing characteristics of a number of important varieties of sugarcane.

(*c*) Experiments for studying special problems. The object of these experiments was to examine more minutely a few important aspects of the process, as distinct from studying the process as a whole. The special experiments consisted of—

(*i*) Comparison of sugar-yielding properties of entire cane, cane with top cut off, and tops only,

(*ii*) Improvement due to the substitution of a removable finishing pan for a fixed one in a *bel*,

(*iii*) Determination of the working capacity of the Bhopal *bel* and its fuel consumption,

(*iv*) Determination of inversion losses during the boiling of juice to first *rab*.

Large Scale Experiments. These tests were carried out with Co. 281 canes (whole canes with tops) on one day and Manjav canes (with the tops cut off) on the second day. The figures for the two tests are given in Table I.

TABLE I.

Working figures for large scale tests.

Particulars		Test number	
		1	2
A. *Variety of Cane*		Co. 281 (whole cane).	Manjav (top cut).
B *Quantities*—			
1. Juice	lbs.	7,063	8,483
2. I Rab	,,	1,575	1,957
3. II Rab	,,	738	..
4. Molasses Gur	,,	..	808
5. I Sugar	,,	683·9	856·4
6. II Sugar	,,	Not machined	..

TABLE I—*contd.*

Working figures for large-scale tests—contd.

Particulars	Test number 1	Test number 2
C. *Yields per 100 Juice*—		
1. I Rab	22·3	23·07
2. II Rab	10·45	..
3. Molasses Gur	..	9·53
4. I Sugar	9·68	10·10
5. II Sugar	2·79 (Calculated).	..
6. Total Sugar	12·47	..
D. *Analyses*—		
1. *Juice*—		
Sucrose	16·67	17·58
Brix	19·59	19·18
Purity	85·08	87·07
Invert Sugar	1·25	0·7
2. *II Rab.*	*II Rab.*	*Gur.*
Sucrose	57·16	52·12
Brix	92·58	96·28
Purity	61·75	54·13
Invert Sugar	13·71	16·00
3. *I Sugar*—		
Sucrose	95·8	95·8
Invert Sugar	1·71	1·62
E. *Efficiency*—		
1. Sucrose in I Sugar per 100 sucrose in juice	55·66	55·03
2. Sucrose in II Sugar per 100 sucrose in juice	15·79 (Calculated).	..
3. Sucrose in Total Sugar per 100 sucrose in juice	71·45	..

In the first test 85·8 mds. (7,063 lbs.) of juice were boiled. The yield of first *rab* was 22·3 per cent. on juice and of second *rab* 10·45 per cent. For want of time the second *rab* was not machined before the close of the experiments, and hence the anticipated yield of sugar from it was calculated on the same basis as in the case of the small-scale experiments. The yield of sugar thus found was—

	Per cent.
Sugar I	9·68 on juice.
Sugar II	2·79 „ „
TOTAL	12·47

Assuming a juice extraction of 66·6 per cent. on cane (which is approximately the average figure for the small-scale tests), the recovery of sugar on the basis of cane was—

	Per cent.
Sugar I	6·45 on cane.
Sugar II	1·86 ,, ,,
TOTAL .	8·31

In the other experiment with Manjav cane (with tops removed) only first sugar was prepared, the resulting molasses having been converted into *gur* (the so-called "Molassein" *Gur*). The yields were—

	Per 100 juice.	Per 100 cane.
Sugar I	10·10	6·74
Gur	9·53	6·35

The percentages on cane are based on an assumed extraction of 66·6 per cent. juice on cane.

The molassein *gur* was of inferior quality, being low in sucrose and purity, and high in invert sugar content.

Both the varieties of cane used for these experiments were of good quality compared with the average cane used in Indian sugar factories, the topped Manjav cane being particularly good.

The first sugar produced was of inferior quality having a polarisation of only 95·8 and containing a large proportion of adhering molasses, as shown by the high invert sugar content. For comparison, it may be stated that even the second grade sugar made in factories has a polarisation of about 98·5 and contains practically no invert sugar. The Khandsari sugar, however, fetches a better price on sentimental grounds, even though it is of such low quality.

The efficiency of the process (that is, the proportion of sugar extracted in first and second sugars calculated as a percentage of the total quantity of sugar present in the juice) is 71·45. The corresponding figure for efficiency of Indian factories is between 85 and 90. The quality of juice treated in the factories is considerably poorer, owing partly to the inferior varieties of cane treated, partly to the canes not being equally fresh (as they have to be brought from long distances) and partly to the more efficient extraction of juice in powerful mills (in which a large proportion of the impurities are also pressed out of the cane).

Small-scale Tests. Eleven such tests were made, the quantity of cane crushed varying from 11·4 mds. to 56·5 mds. in each test. Particulars of the varieties of cane used and the quantities of

different materials (juice, *rab*, sugar, molasses and scum) produced in each test are given in Table II.

The yields obtained (calculated per 100 of cane, juice and *rab*) are tabulated in Table III. The average yields of sugar and final molasses are—

	Per 100 cane.	Per 100 juice.
I Sugar	6·65	10·06
II Sugar	1·94	2·87
Total sugar	8·59	12·93
Final molasses	4·61	6·97

If allowance is made for the fresher and better quality of cane used in these small-scale tests, the yields are similar to those obtained in the large-scale tests.

The analyses of juice, *rab* and other materials are given in Table IV. An account of the sucrose recovered and lost per 100 sucrose in juice is given in Table V. From the average figures given in Table V, it will be observed that out of 100 parts sucrose present in the juice 71·35 parts is recovered as first and second sugar, the balance of 28·65 parts being lost. The average efficiency of the process in these small-scale tests is, therefore, substantially the same as in the large-scale tests. The small-scale tests, although lacking in the realness which characterizes tests on a commercial scale, however, afforded an opportunity for comparing the efficiency of the process for a wide range of varieties and qualities of cane. The tests should help in removing the idea that satisfactory recoveries can be obtained only from S. 48 and one or two other varieties only. They also indicate what varieties should be grown in order to obtain satisfactory results from the process in question.

In order to ascertain the effect of cutting the tops of canes before crushing, on the recovery of sugar an experiment was made using the variety Co. 281. Whole canes, canes with tops cut off and tops alone were crushed separately and their juices were put through the entire process including the manufacture of second sugar. The results are given in Table VI. Briefly the results are as follows:—

	Top cut cane.	Whole cane.	Tops only.
Recovery of total sugar per cent. cane	8·93	8·00	5·69
Efficiency per 100 sucrose in juice	72·72	70·64	60·33

It is evident from these figures that, where possible, it is a good practice to crush only topped canes as the increase in recovery is more than proportional to the increase in sugar content of the topped cane, because the efficiency also increases. In places where the sowing period for cane is long enough, the tops (which are better for sowing than sets cut from entire canes) should be used for sowing and the topped cane for sugar manufacture. This however is not possible in most of the cane tracts of the Northern India.

TABLE II.

Varieties of cane used and quantities of different materials produced in each small-scale test.

Test No.	Variety of cane	Quality	Name of Farm	WEIGHT IN LBS. Cane	Juice	I Rab	II Rab	I Sugar	II Sugar	I Molasses diluted	Final Molasses	Scum
1	Co. 281	Plant	Nishat Afza	3,000·0	2,014·6	428·3	197·75	185·79	54·21	223·25	151·00	44·25
2	Co. 290	Ratoon	Nabibagh	1,472·8	958·9	226·85	99·95	101·95	28·47	136·15	78·20	22·75
3	Co. 213	Plant	Nishat Afza	2,600·0	1,737·9	374·45	167·5	158·71	46·34	237·95	113·00	33·00
4	Co. 281	Ratoon	Nabibagh	2,250·0	1,491·8	339·10	150·85	154·17	46·28	215·0	116·35	27·50
5	S. 48	Plant	Parawlya	4,650·0	3,075·8	738·6	305·30	344·06	92·10	382·05	214·45	50·50
6	Java	Plant	Nabibagh	940·0	639·2	138·50	57·50	64·36	21·35	83·00	36·25	12·25
7	D. 109	Plant	Nabibagh	1,450·0	1,008·6	199·50	88·75	86·30	27·69	124·0	60·25	15·50
8	Co. 221	2nd Ratoon	Nabibagh	2,050·0	1,288·6	295·75	149·75	114·89	36·28	211·25	112·25	32·75
9	Co. 237	Ratoon	Nabibagh	1,320·0	823·4	187·00	78·50	89·36	27·53	112·75	51·25	16·75
10	Co. 213	Plant	From cultivators	3,400·0	2,209·0	496·75	208·00	235·20	60·77	267·25	143·25	39·0
11	Ashey Mauritius	..	..	1,230·0	870·4	181·25	76·50	86·22	21·22	107·25	48·25	17·0
	TOTAL	..	..	24,362·8	16,118·2	3,606·05	1,580·35	1,621·22	462·24	2,099·90	1,124·50	33·25

TABLE III.

Yields of different products in small-scale tests.

Particulars	Average	Test Number 1	2	3	4	5	6	7	8	9	10	11
A. *Yields per 100 Cane*—												
1. Juice	66·16	67·15	65·11	66·84	66·30	66·15	68·0	69·56	62·86	62·38	64·99	70·76
2. I Rab	14·80	14·28	15·40	14·40	15·07	15·88	14·73	13·76	14·43	14·17	14·61	14·74
3. II Rab	6·48	6·59	6·79	6·44	6·71	6·57	6·12	6·12	7·30	5·94	6·12	6·20
4. I Sugar	6·65	6·19	6·92	6·11	6·85	7·40	6·85	5·95	5·60	6·77	6·92	7·01
5. II Sugar	1·94	1·81	1·93	1·78	2·06	2·00	2·27	1·91	1·77	2·08	1·78	1·72
6. Total Sugar	8·59	8·00	8·85	7·89	8·91	9·40	9·12	7·86	7·37	8·85	8·70	8·73
7. I Molasses diluted	8·61	7·44	9·24	9·15	9·55	8·21	8·82	8·55	10·3	8·54	7·86	8·71
8. Final Molasses	4·61	5·03	5·30	4·34	5·17	4·61	3·85	4·15	5·47	3·88	4·21	3·92
9. Scum	1·27	1·47	1·5	1·26	1·22	1·08	1·30	1·06	1·59	1·26	1·14	1·38
B. *Yields per 100 Juice*—												
1. I Rab	22·37	21·26	23·65	21·54	22·73	24·02	21·67	19·78	22·95	22·71	22·48	20·82
2. II Rab	9·81	9·82	10·43	9·64	10·12	9·93	9·00	8·80	11·62	9·53	9·41	8·78
3. I Sugar	10·06	9·22	10·63	9·14	10·33	11·18	10·07	8·55	8·92	10·85	10·64	9·91
4. II Sugar	2·87	2·68	2·97	2·67	3·10	2·99	3·34	2·74	2·81	3·34	2·75	2·43
5. Total Sugar	12·93	11·90	13·60	11·81	13·43	14·17	13·41	11·29	11·72	14·19	13·38	12·34
6. I Molasses diluted	13·0	11·0	14·1	13·6	14·4	12·4	12·9	12·2	16·3	13·6	12·0	12·3
7. Final Molasses	6·97	7·49	8·15	6·50	7·79	6·96	5·67	5·97	8·71	6·22	6·48	5·54
8. Scum	1·93	2·19	2·37	1·89	1·84	1·64	1·91	1·53	2·54	2·03	1·76	1·95
C. *Yield per 100 Rab*—												
1. I Sugar per cent. I Rab	44·9	43·38	44·90	42·44	45·46	46·58	46·47	43·26	38·80	47·78	47·35	47·57
2. II Sugar per cent. II Rab	29·25	27·13	28·48	27·67	30·60	30·16	37·17	31·20	24·23	35·07	29·16	27·74
3. I Molasses (diluted) per cent. I Rab.	58·23	52·12	60·01	63·54	63·40	51·72	59·92	62·15	71·42	60·29	53·79	59·17
4. Final Molasses per cent. II Rab.	71·15	76·35	78·23	67·46	77·12	70·24	63·04	67·88	74·95	65·28	68·87	63·07

Table IV.

Analysis of different materials in small scale tests.

Particulars	Test No. 1	2	3	4	5	6	7	8	9	10	11
A. *Juice*—											
Sucrose	16·42	18·91	16·50	18·09	19·07	17·53	14·59	17·27	18·20	18·05	16·16
Brix	18·99	21·19	18·92	20·19	21·34	19·11	17·27	20·75	20·44	20·15	18·87
Purity	86·48	89·24	87·21	89·58	89·37	91·71	84·50	83·25	89·05	89·55	85·67
Invert Sugar	0·65	0·41	0·64	0·29	0·65	0·77	1·49	1·49	0·69	0·29	1·46
B. *I Rab*—											
Sucrose	72·28	72·91	72·47	72·60	73·58	74·77	70·65	67·62	75·24	74·0	72·25
Brix	87·90	88·49	86·81	90·25	88·97	87·93	87·69	88·49	89·45	91·94	88·49
Purity	82·21	82·39	83·48	80·44	82·70	85·04	80·56	76·42	84·11	80·48	81·65
Invert Sugar	4·80	4·54	5·41	4·74	5·65	4·68	8·73	10·38	5·26	5·82	8·73
C. *II Rab*—											
Sucrose	60·55	62·02	62·67	62·33	62·09	66·17	58·66	54·58	62·51	59·85	57·81
Brix	90·57	87·93	94·19	90·01	91·94	88·49	89·85	91·25	91·70	93·07	89·05
Purity	66·85	70·54	66·53	69·25	67·53	74·77	65·29	59·81	68·17	64·31	64·92
Invert Sugar	9·48	8·26	10·97	9·60	12·59	9·97	14·77	18·73	10·97	12·0	17·45

TABLE IV—*contd.*

Analysis of different materials in small scale tests.

Particulars	Test No. 1	2	3	4	5	6	7	8	9	10	11
D. I *Molasses (Diluted)*—											
Sucrose	..	..	45·37	45·67	52·03	47·69	43·37	40·88	44·15	49·12	41·82
Brix	..	..	67·43	65·86	75·92	65·44	65·39	66·42	65·86	70·78	66·42
Purity	..	..	67·28	69·29	68·53	72·88	66·33	61·56	67·03	69·39	62·97
Invert Sugar	..	..	7·68	6·62	9·14	6·56	11·29	13·24	7·68	8·89	13·71
E. *Final Molasses (Diluted)*—											
Sucrose	41·51	42·59	45·30	42·45	43·06	42·76	38·38	37·29	43·57	43·22	40·73
Brix	79·07	71·93	84·27	71·93	77·95	70·35	77·98	78·85	80·21	85·12	79·07
Purity	52·49	59·21	53·75	59·01	55·24	60·78	49·21	47·29	54·32	50·77	51·52
Invert Sugar	11·63	10·10	13·72	11·64	16·0	12·59	22·59	21·30	17·46	15·30	22·58
F. *I Sugar*—											
Polarisation	97·6	96·6	98·0	96·7	97·9	98·0	97·3	97·0	96·4	96·4	96·0
Invert Sugar	0·71	0·75	0·74	0·66	1·10	0·91	1·22	1·01	0·75	1·07	2·10
G. *II Sugar*—											
Polarisation	96·6	95·4	95·0	95·6	96·2	96·5	96·0	93·8	92·6	94·8	96·6
Invert Sugar	0·81	1·22	1·40	0·66	2·84	1·28	1·81	2·56	2·26	1·87	1·6
H. *Scum*—											
Sucrose	15·0	17·0	14·3	15·8	16·1	19·1	13·3	15·3	16·1	18·0	18·3

TABLE V.

Account of sucrose recovered and lost (per 100 sucrose in juice).

Particulars	Average	Test Number 1	2	3	4	5	6	7	8	9	10	11
A. *Sucrose recovered—*												
1. In I Sugar . . .	55·72	54·81	54·32	54·31	55·26	57·42	56·31	57·04	50·0	57·46	56·87	58·83
2. In II Sugar . . .	15·57	15·83	14·98	15·36	16·40	15·10	18·39	18·06	15·29	17·00	14·45	14·57
Total recovered .	71·29	70·64	69·30	69·67	71·66	72·52	74·70	75·10	65·29	74·46	71·32	73·40
B. *Sucrose Lost—*												
1. In Scum . . .	1·76	2·01	2·14	1·65	1·61	1·38	2·09	1·40	2·25	1·80	1·76	2·21
2. During boiling juice to I Rab (excluding loss in scum.)	5·54	4·40	6·64	3·69	7·14	5·98	5·50	2·88	7·90	4·32	6·02	4·68
3. During boiling Molasses to II Rab.	0·54	..	..	1·05	1·52	1·57	1·09	1·16	2·08	0·47	1·71	0·45
4. During machining and drying I Sugar.	2·5	..	..	2·69	..	1·33	0·76	2·14	1·05	3·20	2·41	2·49
5. During machining and drying II Sugar.	1·7	..	..	3·42	0·15	1·48	1·74	1·61	2·63	0·83	1·25	2·39
6. In final Molasses . .	16·67	18·95	18·37	17·85	18·31	15·74	13·84	15·71	18·80	14·90	15·53	13·97
Total lost .	28·71	..	..	30·35	..	27·48	25·02	24·90	34·71	25·52	28·68	26·60

Table VI.

Experiments with whole and top cut canes.

Particulars	Top-cut cane	Whole cane	Tops only
A. *Analyses.*			
1. *Juice*—			
(a) Sucrose	17·55	16·42	15·77
(b) Brix	19·80	18·99	19·55
(c) Purity	88·62	86·46	80·86
(d) Invert Sugar	0·43	0·65	0·84
2. *Rab I*—			
(a) Sucrose	73·68	72·28	66·89
(b) Brix	89·4	87·9	89·4
(c) Purity	82·37	82·21	74·78
(d) Invert Sugar	3·76	4·80	5·91
3. *Rab II*—			
(a) Sucrose	62·58	60·55	57·74
(b) Brix	91·7	90·5	89·6
(c) Purity	68·24	66·85	64·44
(d) Invert Sugar	8·73	9·48	10·1
4. *Sugar I*—			
(a) Polarisation	96·8	97·6	97·0
(b) Invert Sugar	0·81	0·71	0·77
5. *Sugar II*—			
(a) Polarisation	96·0	96·6	94·0
(b) Invert Sugar	1·20	0·81	1·06
B. *Recoveries*—			
1. Juice Extracted per 100 cane	67·60	67·15	57·34
2. Rab I produced—			
(a) Per 100 cane	14·98	14·27	12·08
(b) Per 100 juice	22·16	21·26	21·08
3. Rab II produced—			
(a) Per 100 cane	6·29	6·59	6·70
(b) Per 100 juice	9·31	9·82	11·68
4. Sugar I produced—			
(a) Per 100 cane	7·02	6·19	4·22
(b) Per 100 juice	10·38	9·22	7·36
5. Sugar II produced—			
(a) Per 100 cane	1·91	1·81	1·47
(b) Per 100 juice	2·83	2·68	2·56
6. Totals sugar produced—			
(a) Per 100 cane	8·93	8·00	5·69
(b) Per 100 juice	13·21	11·90	9·92
C. *Efficiencies*—			
1. Sucrose in I Sugar per 100 sucrose in juice.	57·23	54·81	45·07
2. Sucrose in II Sugar per 100 sucrose in juice.	15·49	15·83	15·26
3. Sucrose in Total Sugar per 100 sucrose in juice.	72·72	70·64	60·33

From an examination of the data contained in Tables II—VI, it is observed that the process gives a higher efficiency with juices which are purer and contain more sugar than with inferior juices, in other words, the drop in the recovery of sugar from poorer juice is more than that caused by a difference in the sugar content of juice alone. Test No. 8 (with Co. 221 second ratoon cane) and the test with Co. 281 topped and untopped canes (Table VI) show this difference in a marked degree.

The effect of this in practice is that all open pan processes are unsuitable excepting where fresh cane, of the best varieties and in optimum condition of maturity, is available. Where this is not the case and the juice contains appreciable quantities of invert sugar and other impurities, the loss of sucrose during open pan boiling is so great that the percentage recovery is seriously affected. The reason for this is that at the high temperature to which the juice is raised in the open pan system, combined with the small elimination of impurities during the crude system of clarification employed, rapid inversion and decomposition of sucrose take place. It is in this respect that the modern factory system (employing vacuum evaporators and pans) has the greatest advantage over the open pan system. It is an unfair comparison to say that the Bhopal system gave an average recovery of 8·59 per cent. total sugar on cane as against about 9 per cent. in sugar factories, or that the Bhopal system shows a boiling efficiency of 71·35 as against 85 to 90 in factories, because the two systems work on entirely different raw materials. The true basis of comparison will be to find out what recovery of sugar or what efficiency of sucrose extraction from juice will be obtained by Bhopal system, if it worked with canes and juices similar to those used in the factories. An approximate idea of this can be formed from the figures given in Table VI. In this test even the juice obtained by crushing the tops alone was of a quality superior to the average juice treated in a factory. But this gave a boiling efficiency of only 60·33, and if the juice had been of a poorer quality and similar to factory juice, an efficiency of not more than 58 could have been expected. It is this figure of 58 which has to be compared with the factory efficiency of 85—90 and not the figure of 71·35 actually obtained with the juices of much higher quality. Under such conditions, the recovery of 8·59 per cent. (obtained in the small-scale tests) would have been reduced to about 6·9 per cent. as compared with 9 per cent. in the factories.

Another consequence of the considerable lowering of efficiency with juices of poor quality is that sugar making by the open pan process is possible only during that part of cane season when the cane is fully mature and at its best. In the beginning and towards the end of the season the recovery of sugar would be so low as to make manufacturing work unprofitable. In consequence of this, whilst the cane crushing season of an average Indian factory lasts from four to five months, with open pan system six to eight weeks is the most that can be expected. The plant therefore remains idle for a much longer period than in a factory.

It may be added that the Bhopal tests were carried out at a time when the cane was fully mature, 18th February to 19th March 1930, being the period during which the cane was harvested.

The total losses of sugar in the Bhopal process are high amounting on an average to 28·65 per cent. of the total sugar in juice. Next to the loss in molasses, the biggest individual item of loss is in boiling juice to *rab* (Table V). As the improvements claimed for the Bhopal system consist mainly in the boiling of juice, a lower figure for loss of sugar at this stage of the process was to be expected.

CHAPTER II.

SPECIAL TESTS.

The tests described so far were carried out with the object of determining the efficiency of the Bhopal system as a method of manufacturing sugar. In addition to these, a few experiments were made for investigating particular aspects of the process. These are described in the following paragraphs:—

Improvement due to the use of a removable finishing pan. One of the improvements incorporated in the Bhopal system is that the "perchha" or the pan in which the concentration of juice is finished is not permanently fixed on the furnace as in the ordinary Rohilkhand *bel*. The pan is removable and is made small enough in size to be easily lifted. When a "Strike" is to be made (that is, when a charge of syrup has been sufficiently concentrated to be taken off the furnace for crystallization and cooling), the pan is lifted off, emptied into the vessel provided for cooling the *rab*, a fresh charge of syrup poured into it from the "Manjha" (or the pan next to the *Perchha* in the train and used for concentrating the syrup) and replaced on the furnace. In actual practice a spare removable *Perchha* is provided for each furnace, one of which is kept on the fire whilst the other is being emptied, cleaned and refilled with syrup.

The object of this modification (which, as is explained later on, is quite common in the Bijnor District) is to prevent the charring of syrup which takes place in a fixed finishing pan every time it is emptied by ladling out the *rab*. To test how far this object is actually served, an experiment was made in which the juice was concentrated as usual in a standard *bel* provided with a fixed pan, but for finishing the syrup, it was sent alternately to (*a*) the fixed finishing pan of the standard *bel* and (*b*) the removable finishing pan of the auxiliary *bel*. The *rabs* produced by the two methods were kept separate and samples taken from them were analysed, the results obtained being as follows:—

	Rab from	
	Fixed pan	Removable pan
Sucrose	69·72	71·6
Brix	88·32	88·32
Purity	78·94	81·24
Invert sugar	8·53	7·68

The actual yields of sugar on machining the two *rabs* are not reported, but the analysis clearly indicates the superiority of the product obtained from the removable pan. The use of the removable pan is a decided improvement in the Bhopal system.

The juice boiling capacity of Bhopal Bels. A series of tests were made for determining the quantity of juice which the standard *bel* (with fixed finishing pan) and the Combined Standard and

auxiliary *bel* can boil per day of 12 hours. The *bels* used were both of eight pans each, the sizes of the pans being approximately the same, excepting for the finishing pans which were smaller in the auxiliary *bel*. Table VII gives the results of the tests and the dimensions of the pans of each *bel*. The tests showed that the Standard *bel* had a capacity of about 100 mds. juice per 12 hours and the Combined Standard and auxiliary *bel* of about 75 mds. The tests were made during the month of March when the density of juice is high.

TABLE VII.

Juice boiling capacity of Bhopal bels:

Particulars	Combined Standard Bel		Standard Bel
	Test I	Test II	
1. Weight of juice boiled . . . lbs.	2,931	8,483	8,292
2. Time for boiling . . . . hours	5-48	14-38	11-0
3. Juice Boiling capacity per 12 hours mds.	84·5	70·7	101
4. Equivalent weight of cane per 12 hours (at 66 per cent. extraction). ,,	128	107·1	153
5. No. of pans in the Bel		8	8
6. Overall length of Bel upto the chimney .	20′ 9″		23′ 4″
7. Diameters of pans— Pan 1 Flat bottomed	2′ 3″		2′ 7½″
,, 2 do.	2′ 5″		2′ 10″
,, 3 do.	2′ 3½″		2′ 9½″
,, 4 do.	2′ 9″		2′ 11″
,, 5	2′ 10″	(Round)	2′ 10½″(Flat)
,, 6	2′ 7½″	(Round)	2′ 10″ (Flat)
,, 7 Round bottomed . . .	1′ 10″		3′ 1″
,, 8 do. . . .	1′ 9″		3′ ½″

Fuel consumption in Bhopal Bels. The supply of sufficient fuel is always a matter of some difficulty in all open pan processes.

Tests were therefore made to find out if the Bhopal system could deal with all the juice obtained from a given quantity of cane, using for fuel the bagasse resulting from that cane unsupplemented by any additional fuel. As bagasse used for fuel is first dried in the sun, it was necessary to find out the quantity of sun-dried bagasse available for every 100 parts of juice. For this purpose,

four separate lots of cane were weighed and crushed. The resulting juice was weighed. The bagasse was dried in the sun and weighed. The weight of wet bagasse was ascertained by difference from the known weights of cane and juice. The results obtained are tabulated in Table VIII. It was found that on an average 26·7 lbs. of dry bagasse is available as fuel for every 100 lbs. of juice extracted. It is necessary, however, to point out that the extraction of juice in these tests was poor. The wet bagasse during the process of drying lost 52·5 per cent. moisture. This shows that a large proportion of juice was left in the bagasse. If a better extraction had been obtained, the quantity of bagasse available per 100 lbs. of juice would have been lower.

TABLE VIII.

Statement showing quantity of dry bagasse available as fuel.

Particulars	Average or total	Test No.			
		1	2	3	4
1. Variety of cane	..	Manjav	S. 48	S. 48	S. 48
2. Mill in which crushed	..	Power	Power	Bullock (Marshall)	Bullock Chattanooga
3. Weight of cane crushed. lbs.	500	200	100	100	100
4. Weight of juice extracted. ,,	320·5	129·5	61·0	64·25	65·75
5. Extraction juice per cent. cane.	64·1	64·75	61·0	64·25	65·75
6. Wet bagasse per cent. cane (calculated).	35·9	35·25	39·0	35·75	34·25
7. Dry bagasse obtained lbs.	85·25	34·0	16·75	16·75	17·75
8. Dry bagasse per cent. cane	17·05	17·0	16·75	16·75	17·75
9. Moisture lost per cent. wet bagasse.	52·5	54·61	57·05	53·12	48·17
10. Dry bagasse produced per 100 parts juice extracted.	26·70	26·26	27·46	26·07	27·00

Having determined the quantity of dry bagasse available for every 100 lbs. of juice, the next test was to find out the quantity

which the Bhopal *bel* consumes in boiling that quantity of juice. The results obtained in the latter test are given in Table IX.

TABLE IX.

Statement showing quantity of dry bagasse consumed as fuel in boiling juice to I rab only.

Particulars		Average or total	Test No. 1	Test No. 2	Test No. 3
1. Variety of cane.		..	S. 48	Manjav	Mixed Cane.
2. Type of Bel used		..	Combined Standard & auxiliary.	Combined Standard & auxiliary.	Standard.
3. Time for boiling	Hrs.	..	5-48	14-38	11-0
4. Weight of juice boiled	lbs.	19,706	2,931	8,483	8,292
5. Weight of bagasse consumed.	,,	5,789·25	921·0	2,631·75	2,236·5
6. Dry bagasse consumed per 100 lbs. juice boiled.	,,	29·37	31·42	31·02	26·97
7. Dry bagasse available per 100 lbs. juice boiled.	,,	26·70	26·70	26·70	26·70
8. Excess dry bagasse consumed per 100 lbs. juice boiled.	,,	2·67	4·72	4·32	0·27
9. Excess dry bagasse consumed per 100 lbs. dry bagasse available.	,,	9·09	17·67	16·18	1·01

They show that the standard *bel* is more efficient than the combined standard and auxiliary *bel* in respect of fuel consumption, as the former is able to boil, under the ideal conditions of the test, the juice with the bagasse available, using almost no extra full, whilst the latter requires about 17 per cent. additional fuel. These figures relate only to the boiling of juice to first *rab*. For boiling molasses to second *rab* extra fuel is required. The fuel efficiency of the Bhopal system cannot, therefore, be regarded as satisfactory. The combined standard and auxiliary *bel*, as stated before, has a higher boiling efficiency than the Standard *bel*, the *rab* produced being of a better quality and the loss of sugar by inversion being less. It is unfortunate therefore that these advantages are partially neutralized by its low fuel efficiency.

Rate of inversion during juice boiling. The statement in Table V giving details of the sucrose (per 100 sucrose in juice) which is recovered and lost, shows that excepting for the loss of sucrose in molasses the greatest loss is during the process of boiling juice to first *rab*. An experiment was. therefore, made for the purpose of studying more closely the rate of inversion as the boiling progresses. The combined standard and auxiliary *bel* was used. To begin with, all the pans were filled with juice and heating was

TABLE X.

Test for determining the rate of inversion of juice during boiling.

Sample No.	Pan No.	Particulars of juice	Period for which heated before sampling	Temperature of Pan	Acidity (in terms of grams H_2SO_4 per 100 grams juice)	Analysis: Sucrose	Analysis: Brix	Analysis: Purity	Analysis: Invert Sugar
		A. Samples taken before transfer of juice from pan to pan was commenced.							
1	Original juice .	Juice from cane crushed at night and sampled at 6 A.M.	0	25°C	0·625	17·70	20·46	86·53	0·68
2	Pan I (Nikhar) .	Heated . . .	1-8	76°C	0·638	17·97	20·53	87·51	0·71
3	Pan 5 (Manjha).	Heated and slightly concentrated.	1-35	99°C	0·646	22·00	25·76	85·40	1·12
4	Pan 8 (Perchha)	A little before striking point.	1-18	106-107°C	2·211	66·53	80·58 apparent.	82·57	4·52
5	Pan 7 (Perchha)	At striking point .	1-25	109°C	2·30	69·33	83·45 apparent.	83·03	4·80
		B. Samples taken after the transfer of juice from pan to pan was commenced.							
6	Pan 6 (Manjha).	After concentration was about half complete.	3-18	99-100°C	1·344	40·42	49·56	81·55	3·12
7	Pan 8 (Perchha)	At striking point .	3-46	109°C	2·476	67·15	83·05	80·86	6·62

Table XI.

Record of time required for manufacturing operations.

Particulars	Test Number										
	1	2	3	4	5	6	7	8	9	10	11
1. Date of boiling I Rab	18-2-30	19-2-30	20-2-30	21-2-30	22-2-30	23-2-30	23-2-30	24-2-30	24-2-30	25-2-30	25-2-30
2. Date of machining I Rab . . .	27-2-30	1-3-30	6-3-30	2-3-30	4-3-30	7-3-30	11-3-30	12-3-30	11-3-30	8-3-30	7-3-30
3. Date of boiling II Rab . . .	27-2-30	1-3-30	6-3-30	2-3-30	4-3-30	7-3-30	11-3-30	12-3-30	11-3-30	8-3-30	7-3-30
4. Date of machining II Rab . .	13-3-30	14-3-30	27-3-30	14-3-30	18-3-30	21-3-30	26-3-30	27-3-30	26-3-30	21-3-30	22-3-30
5. Days I Rab cooled	9	10	14	9	10	12	16	16	15	11	10
6. Days II Rab cooled	14	13	21	12	14	14	15	15	15	13	15
7. Total days from crushing cane to finishing II sugar.	23	23	35	21	24	26	31	31	30	24	25

commenced. The juice was not transferred from pan to pan, till the juice in the *Perchha* (finishing pan) was boiled to the finishing point and a " Strike " made. When this point was reached, the time was noted and the temperature in each pan taken. Samples were taken from four pans and analysed. The data relating to these are noted against samples 1 to 5 in Table X. After this the transfer of juice from pan to pan was commenced and the *bel* began to work normally. Samples were again drawn after some time and analysed. These analyses are noted against samples 6 and 7 in Table X.

From an examination of the results given in Table XI, the following conclusions are drawn:—

(*a*) The inversion is greatest in the *Perchha* (finishing pan) where the temperature is the highest and the concentration of acid is maximum;

(*b*) The longer the juice is boiled, the greater is the loss of sucrose due to inversion, resulting in a lowering of purity.

The usefulness of this test is somewhat qualified by the fact that it was not carried out under actual working conditions. More detailed experiments were carried out at Bilari and the results are discussed in a subsequent section.

Time required in process. A regular record was maintained of the dates on which the different manufacturing operations of each test was made. These are noted in Table XI. It will be observed from this table that the first *rab* took 9 to 16 days for cooling and the second *rab* 12 to 21 days. As compared with the time taken in sugar factories for boiling, cooling and curing Massecuites, the Bhopal system requires about ten times longer for doing the same work. This has serious consequences whilst working on a commercial scale. It means that several weeks' output remains in process at a time, taking up godown space and locking up capital. Moreover, when cane crushing finishes at the end of the season, work on machining the *rab* has to continue for several weeks, involving additional expenditure.

As compared with the average Rohilkhand Khandsari the time taken for cooling the first *rab* under the Bhopal system (9 to 16 days) was longer. Five days to a week is the usual time required. On the other hand, the Rohilkand Khandsaris require much longer (upto a couple of months) for cooling their second *rab* and in this respect the Bhopal results are an improvement.

It may be pointed out that where the *rab* is made for selling and is not to be machined at the *bel* itself, the question of time taken for cooling remains unaffected, because the *rab* cannot be transported till the crystallisation has been completed.

These results have all been obtained by the writer by calculation (when necessary) from the report of Mr. Sanyal for the work described in Part I.

PART II.

The Bilari Experiments.

CHAPTER I.

Purpose and general plan of the Experiments.

Necessity for further experiments. It has already been pointed out in connection with the experiments conducted at Bhopal during February and March 1930 that, owing to shortage of cane, the tests were not conducted on a commercial scale and consequently the results obtained could not be regarded as conclusive. The Sugar Committee of the Imperial Council of Agricultural Research, therefore, decided at a meeting held at Poona on the 11th August 1930, to arrange for and finance a test under commercial conditions, extending over one full season. The Nagalia Farm in Bilari, District Moradabad, was selected as the place where the tests were to be carried out. The Bhopal and Rohilkhand systems were to be worked side by side and the tests were to be on a strictly comparative basis. Chemical control was to be maintained in order to determine the losses at various stages of the two processes and to calculate and compare their efficiencies.

Although it was not expressly stated as one of the objects of the experiment, it was understood that suggestions for improvement and for further research work in the light of the results obtained were also required. For this purpose a few special tests, which would not have been necessary otherwise, were also conducted and some additional technical data collected.

Experiments on the indigenous methods of sugar manufacture have never before been conducted on such an extensive scale. Moreover, whatever experiments have been conducted in the past have been on, what may be called, practical rather than technical or scientific lines. There is consequently no scientific data on the subject available, which could form the basis for correctly appraising the merits of the processes involved or could give indications of the lines on which further work may be done. The Bilari experiments have been utilised for filling up this lacuna so far as it was possible, and the present report has accordingly had to be made more detailed than would have been necessary otherwise.

General Plan of the Experiments. The experiments were to have begun on the 1st January 1931, but owing to delay in the arrival of some of the machinery, work was actually commenced on the 20th January. Cane crushing and juice boiling continued till the 31st March and the machining of rab was completed and the experiment finished on the 24th April. Cane was supplied by Mr. Gupta from his Nagalia farm. The cane was mostly of the Co. 213 variety, a small quantity of Co. 290 and some cane of indigenous varieties being also supplied.

Mr. Har Sahai Gupta was given the control of the entire work. The services of two Chemists, Messrs. P. B. Sanyal, M.Sc., and S. Das, M.Sc., were obtained on loan from the Imperial Institute of Agricultural Research, Pusa, and they were entrusted with the work of chemical control, in accordance with a scheme drawn up by the writer. For supervising the working of the Bhopal system, the services of a supervisor, Mr. Sibte Safdar, L.Ag., were lent by the Bhopal Durbar. Khan Bahadur S. M. Hadi, M.R.A.C., M.R.Ag.S., Director of Agriculture, Bhopal, came to Bilari voluntarily and remained there with a large staff of trained workmen, and personally looked after the work throughout the period during which the experiments were conducted. All work under the Bhopal system was done by Bhopal workmen under Mr. Hadi's direct supervision. A staff of clerks and supervisors was maintained for attending to weighments and seeing that work was done in accordance with the prescribed system. Accurate commercial accounts were kept and special care was taken to ensure that expenditure in connection with the experiments was kept separate from that on general farm work.

As far as possible, the experiments were conducted under normal commercial conditions. Some divergence was, however, unavoidable in consequence of the extra precautions which are necessary in conducting a test of this kind, but this was not considerable. Several interruptions were caused by bad weather and breakdowns of machinery. When these took place, it became difficult to get dry bagasse for fuel and to regulate the supply of cane at short notice. Some accumulation of cane was, therefore, inevitable resulting in dryage and deterioration. Such irregularities are, however, not entirely absent from work under commercial conditions, and hence it has not been considered necessary to make any allowance for them in the results obtained.

Arrangement of the report. The subject-matter of the present report is divided under the following heads, to each of which a separate chapter is devoted:—

(*a*) *Description of the plant and process employed.* It was found necessary to give a description of these so that the basis of comparison for the two processes may be clearly defined.

(*b*) *General working results.* In this section the main working figures like capacities, yields and quality of products are discussed. Similar figures from a local Khandsari, selected at random are also given for comparison.

(*c*) *Comparative costs of the two processes.* The information relates to capital cost as well as working expenses. Figures for cost of production of sugar by the two processes as well as in Indian factories are also given.

(*d*) *Chemical Control data.* Abstract figures for quantities of different materials as well as for average analyses are given in this chapter and are compared for the two

processes. Efficiency factors for each important operation are discussed. Sucrose, brix and invert sugar accounts have been prepared and criticised. For comparison analyses of samples of intermediate and finished products from some local Khandsaris have also been given.

(*e*) *Special Tests.* These cover a wide range of special problems and much useful technical information has been got together. Several questions of special interest like fuel consumption, analysis of flue gases, pH value of juice in different pans and data relating to heating surfaces of pans are included in this chapter.

(*f*) *Recommendations.* Suggestions are made in the final chapter for the lines on which the plant and process may be improved. The necessity for further research on proper scientific lines by the establishment of a research station is emphasized.

CHAPTER II.

Description of Plant and process employed.

Necessity for describing the plant and process employed. The purpose of the experiments at Bilari was to test the Bhopal and Rohilkhand processes of sugar manufacture under commercial conditions. In order to make the test valid, it was obviously an essential condition that the work should be entrusted to people who are thoroughly conversant with it. The selection of Messrs. Gupta and Hadi for this purpose was fortunate. Mr. Gupta and his ancestors have been manufacturing sugar by the Rohilkhand method for generations. Mr. Hadi has been interesting himself in improving the 'Open Pan' system of sugar making for nearly thirty years and has recently developed a modification of the Rohilkhand system, which he calls the Bhopal method, as it was tested on the Experimental farms of the Bhopal State.

In spite of the fact that Messrs. Gupta and Hadi are so well qualified for working on correct lines the processes of which they were placed in charge, doubts have been raised on both sides as to whether the actual plant and process employed were typical of the two processes under trial.

On the one hand, it is pointed out regarding the Bhopal method, that the *bels* used at Bilari for boiling juice to first *rab* and molasses to second *rab* are not of the usual Bhopal type. Mr. Hadi has described the typical Bhopal *bel* in his book, "The Indian Sugar Industry" published in June 1929. The juice boiling *bel* described there consists of four flat-bottomed pans and two round-bottomed pans, both of the latter being fixed. The benefits of removable finishing pans are, therefore, absent from this *bel*. In the experiments conducted at Bhopal in 1930 different types of *bels* were used for different tests. What was called the standard *bel* had eight pans and the finishing pan was fixed. Another *bel* used, which was called "the Combined Standard and Auxiliary *bel*", had two removable finishing pans, the total number of pans being eight. The *bel* used at Bilari had eleven pans, including two removable finishing pans. There is a similar divergence in the design of the Bhopal *bel* for boiling molasses to *rab*. In his book Mr. Hadi advocates the use of *bels* consisting of two pans for this purpose, the clarifier being either flat or round-bottomed. The *bel* used at Bilari on the other hand had three pans all round-bottomed.

Similar objections are raised regarding the Rohilkhand process as employed for these experiments. Some critics contend that the process was not typical and had incorporated several improvements which are as a rule unknown to the average Rohilkhand Khandsari Amongst these improvements (which are said to have been copied

from the Bhopal process) the following are particularly mentioned :—

(a) The filtrate from the scum removed from the clarifying pan was collected in the pan next above instead of in separate earthen tubs (Nands).

(b) The " Chashni " taken out from the *Parchha* (finishing pan) was ladled into three Nands in succession, mixed, aired and cooled till the formation of crystals was perfectly visible and then potted. This procedure, it is said, led to the production of *rab* of homogenous texture and quality, which would not have been the case otherwise.

(c) Tins were used as crystallisers instead of half-baked earthen pots (Kalsis), and thus, it is alleged, a loss of between 3 and 4 per cent. *rab* was avoided in addition to the still heavier loss which occurs on account of the breakage of *Kalsis* in transit from the *bel* to the factory and in the Store-house where some *kalsis* usually burst during crystallisation.

(d) The most important parts of the improved process of boiling the molasses were, it is stated, adopted replacing the usual Rohilkhand methods.

(e) In centrifugalling first *rab* the Bhopal method uses water sparingly so as to reduce the loss of sugar, and this, it is stated, was adopted in the Rohilkhand method also at Bilari.

It will involve one in an almost interminable controversy if an attempt were to be made to substantiate or refute the above claims. All Rohilkhand Khandsaris are not equally conservative in their methods and it is conceivable that there may be many who follow methods even in advance of those adopted at Bilari during these tests. On the other hand, as Mr. Hadi brought his own plant and erected it and supervised the tests personally and as all work was done by trained men brought by him, it can be safely assumed that the Bhopal process was worked at Bilari under the most favourable conditions. It may be added that, under the writer's instructions, the entire manufacturing work of both the processes was in charge of, and supervised by, Mr. Sibte Safdar, Mr. Hadi's assistant from Bhopal.

Whilst therefore it is not necessary to investigate, and record a finding on the point whether the Rohilkhand and Bhopal methods adopted at Bilari were or were not typical, it is essential that the exact details of the plant and process as actually employed should be fully described so that the basis of comparison may be clearly defined. It is with this object in view that the description contained in the following paragraphs, which would otherwise be redundant, is given. For the sake of completeness the cane crushing plant, which was common to both the processes, has also been described.

List of machinery. In addition to work connected with these tests, Mr. Gupta carried on his usual sugar manufacturing business.

For this purpose the cane was crushed mostly in bullock driven country mills provided by petty cultivators, although sometimes after sufficient juice had been supplied to the Experimental *bels*, the power-driven Mills were also used for crushing cane for non-experimental work. There was a separate Rohilkhand *bel* and a ten-pan Bhopal *bel* for boiling the juice thus obtained.

The machinery used for experimental purposes consisted of the following:—

(1) One Ransome's Portable Steam Engine and Boiler, 12 N. H. P. (30 H. P.) for coal burning, for driving the two cane mills.

(2) Necessary countershafting, pulleys and belting.

(3) One three-roller Chattanooga Cane Mill No. 192, top roller 12″ × 12″, bottom rollers 8″ × 12″.

(4) One three-roller Massey's Cane Mill, rollers 12″ × 18″.

(5) One Bhopal *bel*, for first *rab*, consisting of 11 pans.

(6) One Bhopal *bel*, for second *rab*, consisting of 3 pans.

(7) One Rohilkhand *bel*, for first *rab*, consisting of 5 pans.

(8) One Rohilkhand *bel*, for second *rab*, consisting of 2 pans.

(9) Two hand-driven pugmills, capacity 2 c.ft. each (one by Broadbent and the other by Watson Laidlaw & Co., Ltd.).

(10) Three centrifugal machines, with baskets 18″ dia. × 9″ deep, Type 17B, made by Thomas Broadbent & Sons, Ltd., each complete with separate petrol-kerosene engine $2\frac{3}{4}$ B. H. P.

(11) One centrifugal machine with basket 18″ dia. × 9″ deep by Messrs. Thomas Broadbent & Sons, Ltd., hand driven by gearing and rope.

(12) 2,000 empty kerosene tins for carrying juice and storing (or "Potting") *rab*.

(13) One platform weighbridge, 20 cwts. capacity, for weighing cane.

(14) One platform weighbridge, 5 cwts. capacity, for weighing *rab* and sugar.

(15) Four-pattas for drying sugar.

Cane crushing. The varieties of cane grown at the Nagalia farm were Co. 213 and Co. 290 of plant growth (that is first year's crop), but sometimes indigenous as well as improved varieties of cane obtained from outside cultivators were also crushed for experimental purposes. The cane was cut and stripped in the fields (which were situated at a distance of about a furlong), carted to the factory, unloaded and weighed on a one-ton platform weighbridge, and passed on to the cane mills for crushing. As far as possible cane was crushed on the day it was received from the fields, but sometimes it was delayed for two or three days.

PLATE II.

The Bhopal *Bel* for juice boiling
(with front wall partially removed).

There were two cane mills for use in connection with these tests. One of these was a three-roller Massey Mill with rollers 12″ dia. × 18″ long, and the other a three-roller Chattanooga Mill No. 192. Full particulars of both these mills are given in Table XII.

Both the Mills were driven from a Common Countershaft which itself was driven by a portable Steam Engine of 30 H. P.

Juice Boiling (a) *Bhopal Method*. The particular Bhopal *Bel* used for these tests consisted of eleven pans, seven of which were flat-bottomed cylindrical vessels and four round-bottomed bowl-shaped pans. Of the latter, the two smallest ones, which were used as finishing pans, were removable, all the other nine being fixed to the furnace. There were, in addition, two spare finishing pans, which were used for replacing the two in use, when they were removed for pouring off the finished *rab*. Four iron pans (two for each *parchha*) were used for aerating and cooling the *rab*.

The construction of the furnace is similar to that of a Rohilkhand furnace. The flue leading from the furnace to the chimney, and passing under all the pans, differs from the flue of a Rohilkhand *bel* in having a gentler shape. The furnace and pans are shown in Drawing A which is based on actual measurements taken at Bilari. As all details are given in this drawing, it is not necessary to enter into a lengthy description here. The photograph in Plate II shows a front view of the *bel*.

The three pans Nos. 1-3 are called *Hauz* and are used for receiving and storing of juice, although when, as sometimes happens, the juice in these becomes heated to near the boiling point, it is clarified in them and the pans then serve the purpose of *Nikhar* or Clarifiers. All the seven flat-bottomed pans have the same depth, which is 18 inches. The diameters of the three *Hauz* pans Nos. 1, 2 and 3 are 36, 37 and 38 inches respectively.

The next four flat-bottomed pans, Nos. 4, 5, 6 and 7, have diameters of 39, 40, 41 and 42 inches respectively. They are called *Nikhar* pans and are used for clarifying and skimming the juice.

Pan No. 8, called the *Khaula*, is a round-bottomed vessel 3′ 6″ diameter and 15″ deep. The juice entering this should have been completely clarified in the preceding pans. In the *Khaula* the juice is boiled vigorously with the object of evaporating bulk of the water in a short time. Any scum coming to the top is removed.

Pan No. 9 measures 3′ 2″ dia. × 14″ deep. It is called the *Manjha* and is, as the name implies, an intermediate pan between the *Khaula* (or boiling pan) and the two *Parchhas* Nos. 10 and 11 (the finishing pans). In the *Manjha* which is placed directly over the fire, the concentration of juice is carried a step forward. A sheet iron channel is placed between pans Nos. 8 and 9 and over pans Nos. 10 and 11, so that when juice is ladled from pan No. 8 to pan No. 9, any dripping may not fall into pans Nos. 10 and 11 which contain almost finished *rab*.

The two *Parchhas*, pans Nos. 10 and 11, are made small, measuring 20″ dia. × $6\frac{1}{2}$″ deep each, and are light enough to be removed by hand when the syrup in them has reached the desired consistency for finishing. The use of removable *Parchhas* prevents burning and caramelization of *rab* at the time of making a strike when only a small quantity of *rab* is left in the pan, mostly adhering to the sides and exposed to the full heat of the fire. The removable *Parchhas* constitute the principal improvement embodied in the Bhopal *Bel*, and will be considered in more detail later on. It is sufficient to point out here that the idea of a removable finishing pan is not in itself a new one. The *bel* used for juice boiling in the district of Bijnor, not far from Bilari, consists of three pans, the middle one being the removable finishing pan. One such *bel* was installed for instructional and experimental purposes some years back at the Technological Institute in Cawnpore, and is still in use there. Drawing No. B has been prepared from dimensions taken from this *bel*. An examination of this drawing shows the close resemblance between the Bijnor type of *Bel* and the front portion of the Bhopal *Bel*, excluding the seven flat-bottomed pans.

The method of working the *Bel* may now be described.* Before starting boiling operations, the *parchha* arch is bricked up. About three quarters of a tin of juice is put into each of the two *parchhas* and $1\frac{1}{2}$ tins of juice into the *Manjha*. The *Khaula* is filled with about 8 tins of juice and the remaining pans with 4 to 5 tins, unless juice is available in sufficient quantity to fill them all up to their full capacity. Care must be taken, however, to start boiling as soon as possible to avoid any risk of fermentation of juice. One or two tins of clean cold water, one or two tins of the defecating agent (extract of *Bhindi*, *Deula* or *Semal*), a tubful of saturated lime water and a boiled solution of *Sajji* (usually boiled in the last pan of the *bel* before putting in juice) in a tin, should all be previously prepared and kept handy. The subsequent operations are thus described by Mr. Hadi in his book (*vide* pages 125-128):—

> "Fire should then be applied and feeding through the Bilaiya continued zealously (by even two feeders if necessary) so as to sufficiently heat the furnace within an hour or so. In 10 to 15 minutes the juice in the *parchha* should attain the boiling temperature when clarification should be done by adding the mucilaginous defecants, ebullition being controlled by addition of cold water when necessary. By the time the defecation is complete, and sometimes a little earlier, the juice in the *Manjha* will be ready to undergo the clarifying process, which should at once be taken in hand. It very often happens that the clarified liquor in both of these pans shows a tendency to overflow. Should it be found difficult to check it by addition of cold water, part

* See Hadi's "Indian Sugar Industry", page 125, for a detailed description.

of the clear liquor should be taken out into a tin in order to replenish the two pans at intervals and to keep them boiling until the juice in the *Khaula* has been clarified. Saturated lime water should be used sparingly as soon as the liquor becomes transparent, in each case *sajji* solution being put in before liming. In order to save fuel, labour, and time, and to avoid as far as possible any avoidable increase in the volume of the liquid requiring concentration, the Rohilkhand boiler is averse to introducing the mucilaginous liquid defecant in quantities sufficient to ensure complete liberation of the separable nitrogenous bodies contained in the juice, with the result that the liquor obtained by him in the *Khaula* or *Nikhar* is singularly wanting in clearness and is loaded with finer particles of impurities in suspension. This procedure should be looked upon as bad economy. No less than a tinful of the liquid defecant has been found to be the quantity adequate for clarifying 8 tinfuls of juice. Care must also be taken to introduce the mucilaginous liquid after the temperature of the juice has risen to the boiling point and the cracking of the scum layer on the top has well advanced, and not before. With fall in the temperature, which follows, any separable particle still contained in the juice is set free and it ascends to the top, whence it is easily removed with the thick layer of the scum. If it is found that the waves of impurities do not continually travel from south to north, it should be concluded that the fault lies in construction of the furnace, which must be remedied when the furnace is cooled down, by removing the *Khaula* or the *Nikhar* pan, as the case may be, from the furnace and so rectifying dimensions of the oven below that it may receive the highest degree of heat at the southern end, and the boiling must not be allowed to originate except in that part of the pan. Too much emphasis cannot be laid on the necessity of faithfully observing this important rule, as neglect to do so would only result in bad clarification and defects in the quality of the massecuite.

When a fairly clear liquor has been obtained, the *sajji* water should be more freely used than is the rule in Rohilkhand. At the time of using this agent, however, the fire must be lowered by reducing the rate of feeding at the Bilaiya, otherwise the violent ebullition which follows its introduction into the pan may be too severe, causing an uncontrollable overflow. Besides, the chemical and physical changes due to the agent take place better at a temperature below the boiling point. It is well known in Rohilkhand that the use of *Sajji* beyond a certain limit darkens the colour of the resulting *rab* and therefore affects adversely the market price of it. The Rohilkhand boiler is therefore exceedingly unwilling to use it except sparingly. He is ignorant, however, of the fact that although the excess of *Sajji* may darken the colour of the *rab*, the use of it, in larger quantities than is so far

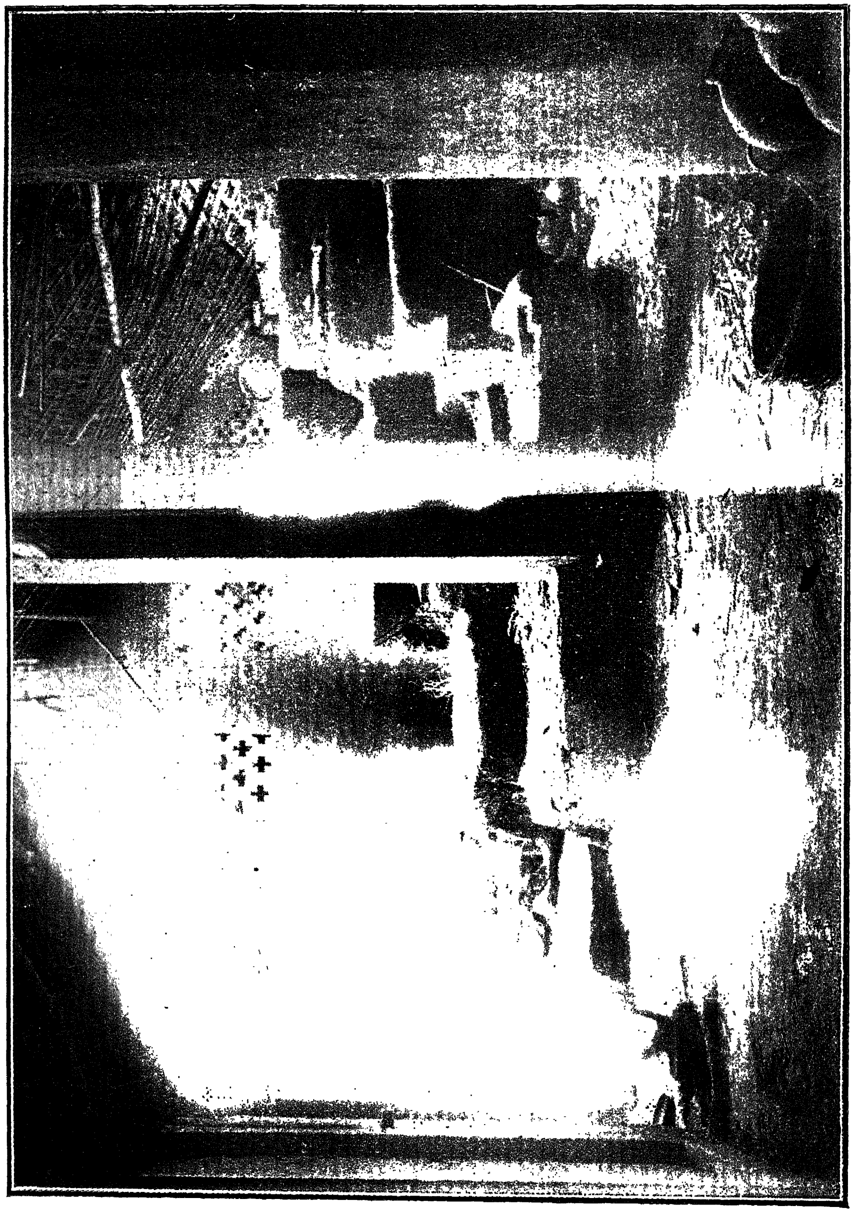
believed to be permissible, very remarkably favours formation of a heavier crop of strong crystals in the *rab* while cooling, and the dark or darkish *rab* obtained yields a perceptibly higher percentage of normally white *Khand* in the centrifugal. The author has seen on several occasions that the *rab*, nearly as dark as the Indian bazar ink, obtained as a result of use in excess of *Sajji*, has given highly satisfactory results both as regards the quality and the quantity of the sugar (both first and second) in the machine. Whether the Sewar weed will effectively bleach such dark coloured *rab* in the *Khanchi* system, the author is unable to say, having never had an opportunity of trying it in the *Khanchi*. But it can safely be recommended that where manufacture of *rab* is intended for treatment in the centrifugal, *sajji* water should be used in quantities two to three times as large as employed now in Rohilkhand, and a highly rich *rab*, conspicuously free from viscosity, thus obtained. Indeed it is with such specimens of *rab* that between 50 and 58 per cent. of white sugar was obtained on curing. The colour evil can be removed at least partially by subsequent introduction of small quantities of sodium hydrosulphite in the liquor (after *Sajji*) until it is found that the chemical does not exercise any further bleaching action. The said chemical may be introduced perhaps with greater advantage in the *Parchha* three or four minutes before the required consistency of the *rab* is achieved. In manipulating the juice of the red canes, usually rich in colouring matters, the use of the hydrosulphite is strongly recommended as it certainly improves the colour of the *rab* and there are reasons to think that it also increases the amount of crystals though it cannot be said definitely that the latter is invariably the result. If, however, the object is to produce white sugar having large and brilliant crystals, the use of *Sajji* in excess should be avoided and that of lime water entirely dispensed with.

As soon as the clarification and sulphitation with the *Sajji* are over, the temperature of the liquor should be raised again by the continuous feeding of the furnace and a boiling temperature maintained till the contents of the pan are transferred to the lower vessel. It must be carefully borne in mind that the use of the hydrosulphite in excess results in the production of yellow or pale sugar. It is therefore important to use it very sparingly.

These remarks apply equally to the *Khaula* or *Nikhar* whichever vessel may be used for the time being for carrying out the clarification process. The *Khaula* usually serves the purposes of a clarifier in the first charge, thereafter the *Nikhar* is the vessel in which the juice undergoes clarification.

Lastly, the main purpose of the first pan (*Hauz* I) is to receive from time to time the juice transported from the

PLATE III.



The Rohilkhand *Bel* for juice boiling.

crushing yard and to heat it to the varying degrees of temperature possible at different hours in the natural course. As has been stated before, if there is at any time more juice than this pan is able to hold, the excess should remain temporarily in kerosene tins or collected in a spare pan near by. When the boiling operations are well advanced, the juice in *Hauz* I becomes quite hot, and attains the high temperature necessary for normal clarification. The rising scum should, when the top layer becomes fairly thick, be gently removed and transferred to the filter. As soon as *Hauz* II is empty, the partially clarified juice should be ladled into the last named pan and its place taken in *Hauz* I by juice fresh from the mill.

In Rohilkhand it is customary to pot the *rab* in earthen jars known as *Kalsis*. The author has however used kerosene tins and found them more advantageous. The earthen jar has to be broken in order to take the *rab* out for curing. Minute particles of the broken jar usually get mixed with the *rab* and can never be separated from the resulting sugar. This feature affects the quality of the sugar. If tins are used for storing the *rab*, this particular disadvantage is avoided and the same vessel can be used several times for potting. *Rab* may be stored perfectly well in large iron crystallisers or masonry tanks.

Before the final product is potted and as soon as it has been discharged from the *Parchha* into the *Nand* (earthen receptacle), it should be "aired", *i.e.*, subjected to the process known in Rohilkhand as *Osa dena*. It consists in stirring the *rab* with a "Dori" (a cup to which a handle is attached) lifting it and pouring it back into the *Nand* so as to bring the mass frequently into contact with cool air. The operation is repeated for 10 to 12 minutes and is meant to bring about crystallisation in motion."

Juice Boiling (b) Rohilkhand Method. The *bel* used at Bilari was of the usual Rohilkhand type, consisting of five pans. The dimensions of these as well as full details of the furnace and flue are shown in Drawing D. Plate III shows a side view of the *bel*. The first pan called the *Hauz* is used for storing the raw juice and measures 7′ 5″ dia. × 2′ 4″ deep. The necessity for having such a large pan for storage of juice arises because of the fact that the usual custom in Rohilkhand is to purchase juice from cultivators who instal their own mills near the *bel*, crush the cane cut from their fields and supply the juice to the *bel* as soon as a sufficient quantity has been obtained. For this reason the supply of juice is intermittent and arrangements for storage become necessary. That this storage capacity has been provided in a pan placed on the flue has the advantage of utilizing some of the heat which would otherwise have gone to waste. In places (for example on farms) where the *Khandsari* crushes his own cane and feeds the juice to the *bel*, a continuous supply of juice is available and the

storage pan is not required. The writer saw two Rohilkhand *bels* near Bilari, consisting of only four pans each as both of these were receiving juice from power-driven cane mills worked by the owners of the *bels*. In Bilari also, during the present experiments, the storage pan was never properly filled as the juice was being passed on to the other pans as soon as it was received from the mill.

The pan next to the *Hauz* is called the *Nikhar*. It measures 6′ 10″ dia. × 22″ deep. It is used for clarifying the juice by adding the mucilaginous extract of *Deula* and *Sajji* solution, followed by skimming. The scums are thrown on a strainer made by spreading a piece of coarse cloth over a basket placed above the preceding pan.

The next pan measures 5′ 8″ dia. × 20″ deep and is called the *Khaula*. The clarified juice is ladled into this from the *Nikhar* and is boiled vigorously. Some scum forms again, is skimmed off, and thrown on to a cloth strainer placed over the *Nikhar* pan.

The next pan below the *Khaula* is called the *Phadka*. It measures 4′ 9″ dia. × $10\frac{1}{2}$″ deep. In this the concentration of the juice proceeds further, till it reaches the consistency of syrup.

The last pan in the train and the one directly above the fire is the *Parchha* or the finishing pan. This measures 3′ 3″ dia. × $8\frac{1}{2}$″ deep and is set so that its top is 6 to 7 inches below the floor level. The syrup coming from the *Khaula* is boiled in this pan till it has reached the point at which it is ready for " Striking ". The finishing point is judged by experienced workmen from the shape and size of the bubbles formed on the surface and from the sound which the bursting of these bubbles makes. Even at night, whilst working in the dim light of a kerosene lamp, a skilled workman is able to make strikes at the right consistency. The striking temperature was noted on several occasions and was found to be always between 110° C. and 111° C.

There is a considerable amount of frothing in the last three pans (the *Khaula*, *Phadka* and *Parchha*), and if this becomes so violent as to entail a risk of overflowing, an aqueous extract of crushed castor seeds is sprinkled over the surface. and the froth subsides immediately.

As the evaporation proceeds in the *Phadka* and *Parchha*, the syrup adhering to the sides at the top becomes solidified. To prevent this getting burnt, it is, from time to time, wiped off with a grass brush tied to a stick, the brush being subsequently dipped into the preceding pan and the adhering semi-solid material is washed off. No caramelization therefore takes place and the surface of the pans above the level of the boiling juice always remains clean. It should be observed that the vertical-sided pans of the Bhopal *bel* have an advantage in this respect as any accumulation of adhering material takes place at a level where there is no risk of burning. As against this, it should be noted that the four pans (the *Khaula, Manjha,* and the two *Parchhas*) where the syrup is more concentrated and where the temperature is also high,

involving risk of caramelization, are bowl-shaped and not vertical-sided and are therefore at the same disadvantage as the pans of the Rohilkhand *bel*.

It was observed during the working of this *bel* that the scum coming to the surface of the juice in all the pans, and particularly in the *Nikhar* and *Khaula*, always collected on the side of the pan away from the furnace. This is an improvement over the Bhopal *bel* in which the scum accumulates on the opposite side, as after skimming, the scum has to be transferred to the basket placed on the preceding pan. To do this in the Rohilkhand *bel*, the scum has not to be carried across the pan which has been skimmed, as in the case of the Bhopal *bel*. The reason why the scum separates in this manner in the Rohilkhand *bel* is to be found in the manner of setting the pans, and in the steep slope of the flue through which the hot gases travel under the pans. The combined effect of these two factors is that the hot gases impinge directly on that portion of the under-surface of the pans which faces the furnace. This portion therefore gets hotter than the rest of the pan, the juice in the pan in contact with this gets heated more rapidly, rises to the surface towards the side nearest the furnace and travels along the surface to the side nearest the chimney, carrying the scum with it to that side. The scum is left here and the juice continues its cycle of circulation downwards. From this point the scum is easily removed and transferred to the basket strainer placed directly above it. For achieving the same object of getting the scum to separate on one side conveniently for removal, the flat-bottomed pans of the Bhopal *bel*, if set in an ordinary level position, will be unsuitable. Hence it becomes necessary to set them in a sloping position and to cover their back portions with clay in order to prevent heating there and thus securing unilateral circulation of juice. The drawbacks in this are firstly that the portion of the heating surface of the pan which is covered with clay is rendered ineffective (thereby reducing the juice boiling capacity) and secondly that (as already stated) the scums accumulate on the wrong side of the pan.

Reverting once more to the consideration of the boiling operations in the Rohilkhand *bel*, the finally concentrated syrup which is ready for striking is ladled out of the fixed *parchha* into a channel from which it flows into the first of a series of three earthen tubs set in the ground. The ladling out is done as quickly as possible and when the *parchha* is almost empty, a fresh charge of syrup is transferred into it from the *Phadka*. The *rab* which has been transferred to the earthen tub is aerated by taking out portions of it in a cup with a handle and letting it drop into the tub from a height. The sudden cooling which thus takes place disturbs the unstable equilibrium of the supersaturated solution and crystallization immediately sets in. The process of aeration is continued till the requisite amount of crystallization (which is known from experience) has taken place. Meanwhile the *rab* is

transferred from the first to the second tub and thence to the last one. The *rab* thus gets mixed with the product of previous strikes and a more homogenous material is obtained. After the cooling has proceeded to the desired extent, the *rab* from the last tub is "potted", that is filled into tins, which are put aside and left undisturbed for ten or twelve hours, at the end of which time they are transferred to the store house. They are kept here for about a week after which they should be ready for machining.

When the *rab* is ladled out of the *parchha*, a small quantity is always left at the bottom, adhering to the sides. As the *Parchha* is directly over the fire, burning and caramelization takes place even during the few moments that elapse before a fresh charge is transferred from the *Phadka*. Inversion of sucrose and charring take place reducing the proportion of recoverable sugar and imparting a dark colour which it is difficult to eliminate later on. Moreover the molasses obtained from such a *rab* does not give good second *rab* on re-boiling and the resulting second sugar is also of an inferior quality. The removable *Parchha* used in the Bijnor and Bhopal *bels* has the advantage that no burning can take place. This is one of the reasons why more and better second sugar is produced by the Bhopal method.

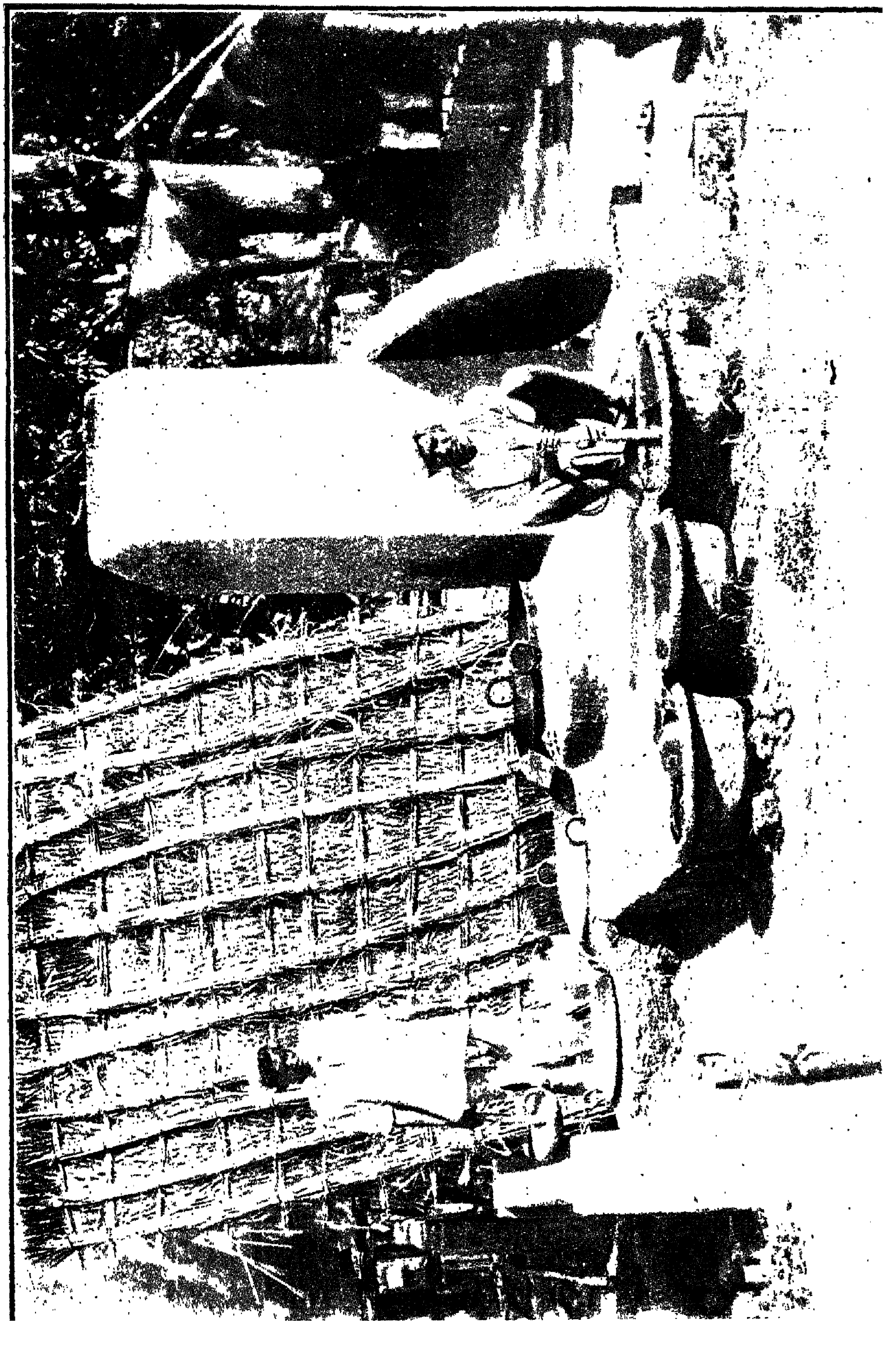
Molasses Boiling (a) Bhopal Method. The Molasses boiling *bel* used in the Bhopal process consists of three pans. The dimensions of the pans and the general construction of the furnace are shown in Drawing B. A general view of the *bel* is given in Plate IV. The first pan, which is used for clarification, measures 30 inches dia. $\times$ $11\frac{3}{4}$ inches deep. The next pan, where concentration and skimming take place, is 27 inches dia. $\times$ $8\frac{1}{4}$ inches deep. The last pan is the *Parchha*, measuring 20 inches dia. $\times$ $6\frac{1}{2}$ inches deep. The *Parchha* is removable. There are three earthen tubs provided for aerating and cooling the second *rab*, till it is ready for potting.

For boiling second *rab*, the molasses obtained from the centrifugal machines whilst machining first *rab* is mixed with the washings from the pugmill, the tins in which the *rab* was stored and the centrifugal machines. The density of the dilute molasses should be 65°—70° Brix. The object of this dilution is twofold, —firstly all sugar crystals are dissolved (thus avoiding trouble during subsequent crystallization of second *rab*) and secondly when the liquid is thin, the suspended impurities rise to the surface more easily during the process of clarification and skimming. For defecation, saturated lime water is used.

The process of emptying the *Parchha* by removing it from the furnace and aerating and cooling the *rab* is similar to that followed in the juice boiling *bel*, which has already been described.

Molasses Boiling (b) Rohilkhand Method. The *bel* used for boiling molasses into second *rab* by the Rohilkhand method consists of two pans. The details of the *bel* are shown in Drawing E. Plate V shows a general view of the *bel*. The first pan measures

PLATE IV.



The Bhopal *Bel* for molasses boiling.

PLATE V.

The Rohilkhand *Bel* for molasses boiling.

5 ft. dia. × $13\frac{1}{2}$ inches deep and the second pan used for finishing the boiling is 3 ft. dia. × $9\frac{1}{4}$ inches deep.

The dilution of molasses as well as defecation by means of lime water are done in the same way as described above for the Bhopal method. The Rohilkhand *bel* however did not work satisfactorily for several reasons. Firstly, the molasses which was reboiled was of an inferior quality due to the first *rab* from which it was produced having deteriorated owing to burning in the *Parchha* of the juice boiling *bel*. Secondly, the first pan of the molasses boiling *bel* was too big and it never got sufficiently heated. For all practical purposes it served no other purpose than that of storing the molasses, and the *bel* really consisted of only one pan. Thirdly, the entire process, consisting of liming, skimming, concentrating and finishing, had to be done in the *Parchha*, and it was impossible to do all this effectively in a single pan. Fourthly, the *parchha* was fixed and the finished *rab* had to be removed from it by ladling out, involving all the disadvantages enumerated under the Rohilkhand juice boiling *bel*, with only this difference that as the molasses *rab* contains more invert sugar and other easily decomposable constituents, the losses due to overheating are bound to be much heavier.

The second *rabs* were allowed to crystallise for about 20 days in the case of the Bhopal method and 25 days in the Rohilkhand process.

Clarifying agents and chemicals used. The method of clarification employed in the Bhopal and Rohilkhand processes has already been explained. The principal clarifying agents used for this purpose are described below:—

(a) *Deula* (*Hibiscus ficulneus*).—The freshly cut green stems of the plant, which grows wild, are pounded in water and rubbed between the hands with the addition of more water. A mucilaginous colourless liquid is produced which has a thick consistency when poured out. The extract is used for clarifying juice. It contains certain vegetable albumens which coagulate on heating, entangle the suspended impurities of the juice and bring them up to the surface, where they are skimmed off. The scum is at first of a dirty dark green colour but later on, as clarification becomes complete, it becomes a white froth consisting mainly of steam and juice.

(b) *Bhindi* (*Hibiscus esculentus*).—This is a cultivated variety. The extract is prepared from the stems and used in exactly the same manner as extract of *Deula* stems. *Deula* however is to be preferred, as it is more effective.

(c) Bark of *Semal* tree (*Bombax malabaricus*) and bark of *Falsa* tree (*Grewia asiatica*).—Extracts of these are also used for clarifying juice. They are however not as efficient as *deula* or *bhindi*, and are used only when the latter are not available.

(*d*) *Sajji* (a mixture of crude sodium carbonate and sodium sulphate).—A sample of *Sajji* was analysed and was found to have the following composition:—

	Per cent.
Na_2CO_3	50·9
Na_2SO_4	6·42
NaCl	4·43
Organic matter	2·75
Insoluble matter	7·71
Moisture	27·79

A solution of *Sajji* in water is prepared and is boiled before use. *Sajji* solution is added to the boiling juice after clarification with *Deula* and skimming are complete. A copious evolution of carbon dioxide takes place, and the heavy froth which forms consists chiefly of gummy impurities of the juice which are skimmed off. A strong smell of sulphur dioxide is also noticed, due probably to the breaking up and reduction of sulphates. The sulphur dioxide exercises a bleaching action on the juice. It is for this reason that the use of *Sajji* is preferable to sodium carbonate or bicarbonate, which do not contain any sulphur. Strong alkalies have also a tendency to form dark-coloured compounds in the presence of invert sugar, which eventually impair the colour of the finished sugar.

(*e*) *Lime water*.—Milk of lime is never used. Saturated lime water which is quite clear is added to juice after the clarification with *Deula* and *Sajji*. Lime water is of special advantage whilst treating juices from inferior or diseased canes. The quantity used is very small and is judged by experience, and not by test papers.

(*f*) Sodium hydrosulphite (or Blankit).—This is a bleaching agent and is used in small quantities for reducing the dark colour of juices from certain varieties of cane. It is added after clarification and addition of lime water.

(*g*) *Castor Seed extract*.—The extract is prepared by soaking crushed castor seeds in water. An emulsion of castor oil and water is produced. After clarification of juice, when it reaches the stage of rapid boiling, frothing takes place. Castor seed extract is sprinkled on the juice and helps in subsiding the froth.

(*h*) *Stannous chloride*.—A very weak solution is used for final washing of sugars in the centrifugal machine. It has a bleaching effect.

Tools and implements used.—Drawings C and F show the tools and implements used in the Bhopal and Rohilkhand processes respectively. The items used for juice boiling and molasses boiling are shown separately and the number of each required is also

mentioned. The purpose for which the various tools are used is explained below:—

(*a*) *Karanga.*—A ladle for transferring juice from one pan to another.

(*b*) *Dori.*—A ladle of smaller size than the *Karanga*, used for aerating the *rab* for inducing crystallization.

(*c*) *Pauna.*—A perforated ladle for removing the scum from boiling juice. The perforations permit of the juice being drained off, whilst the scum is retained on the ladle.

(*d*) *Adha.*—A perforated ladle similar to a "pauna" but of smaller size.

(*e*) *Khurpi.*—A scraper, for scraping solidified *rab* from sides of pans.

(*f*) *Chhanna.*—A filter or strainer for juice or scum.

(*g*) *Donga.*—A large ladle for transferring juice or hot *rab*.

(*h*) *Sabar.*—An iron rod with a flattened end, used for breaking crust of *rab* in tins.

(*i*) *Tipai.*—A wooden frame for supporting the basket over which a cloth strainer is tied for filtering the scums.

Centrifugalling of first and second rabs. The three machines used for centrifugalling the first and second *rabs* of both the processes were of the same type, and there was no difference in the method of operating them. One hand-driven machine was also set up for trial. The machine itself was of similar construction to the three power-driven machines, but for driving it a separate gearing mounted on a wooden frame was provided. This had handles on both sides for applying manual power, and a rope drive was used for transmitting power to the machine. The arrangement failed to work satisfactorily as it was found impossible to apply sufficient power by hand to enable the machine to work at the desired speed. It is possible that more satisfactory results may be obtained if this type of drive is used in conjunction with machines of smaller sizes.

All the machines are fitted with three screens each, the innermost one consisting of a coarse copper wire gauze 26/30 with a twilled weave, the one next to this being copper gauze of 70 mesh (that is having 4,900 apertures per square inch), the last one on the outside being the perforated drum of the machine.

The engine used for driving this type of machine has a rated speed of 560 R. P. M., but it can be run at higher speeds. The normal speed of the machine is 1,800 R. P. M. or a peripheral speed of the cage of about 8,500 ft. per minute. The engine is provided with a regulator for adjusting the feed of oil and thus reducing or increasing its speed. In operating the machine, the speed is kept low (about 1,600 R. P. M.) at first till the greater portion of the molasses has escaped, after which the throttle is opened and the speed increased to 2,000 to 2,100 R. P. M.

The engines were not found very satisfactory in working. They are not robust enough for working by unskilled labour and the

cost of fuel is also high. A simple type of engine of stronger construction would be preferable. In localities where electric power is available, variable speed motors will be more suitable.

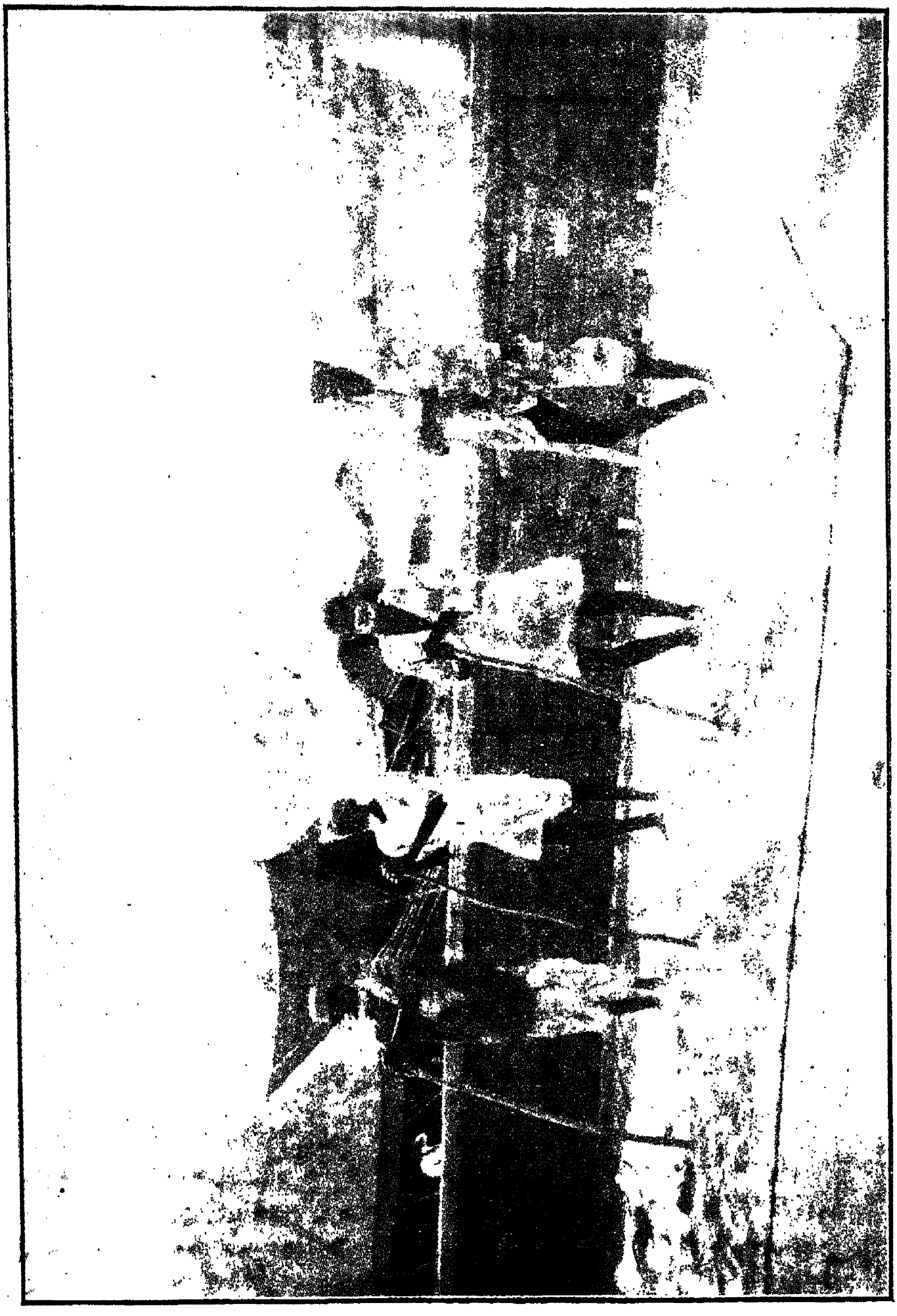
As regards the method of machining the *rab*, there is no special feature to be noted. The methods commonly employed are described in a connected form in the Annual Report of the Department of Agriculture, Bhopal, for 1928-29 and an extract of the relevant portion is given in Appendix A.

Drying of Sugar. Wet sugar obtained from the Centrifugals by both the processes was dried in the sun by spreading it on a *Pata* (thick gunny carpet) and treading over it bare-footed. Lumps of sugar become disintegrated in the process, crystals are broken and the sunlight exercises a bleaching effect. The alternative method of crushing the sugar with a wooden roller worked by hand over a plank of wood was not employed.

TABLE XII.

Particulars of cane crushing mills.

Serial No.	Particulars	Massey Mill	Chattanooga Mills
1	Size of rollers—		
	Top	12″×18″	12″×12″
	Bottom	12″×18″	8″×12″
2	Setting of rollers—		
	Feed	5/16″	5/16″
	Discharge	3/16″	⅛″
3	Speed of rollers—		
	(a) R. P. M. Top roller	4	5
	(b) Peripheral speed, top roller	12·5	15·6
4	Roller grooving—		
	(a) Circumferential, depth	1/16″	1/16″
	number per inch	6	6
	(b) Chevron, number per roll on all rollers	6	6
	Depth	3/16″	3/32″
	Width	¼″	¼″
5	Flanged rollers	Bottom only	Top only.
6	Gearing	Double reduction.	Double reduction.
7	Gearing ratio	27·5 : 1	19·5 : 1
8	Pulleys	Fast & Loose	Fast only.
9	Pulley dimensions—		
	(a) Face	6″	7″
	(b) Diameter	30″	40″
	(c) R. P. M.	110	78
10	Belt—		
	(a) Type	Canvas	Canvas.
	(b) Width	6″	5″
	(c) Thickness	⅜″	⅜″
11	Speed of belt, feet per minute	864	817
12	Cane feeding shoot	Not provided	Provided.
13	Bagasse Carrier	Not provided	Not provided.
14	Juice Pump	Do.	Do.
15	Performance—		
	(a) Cane crushed per hour (average for season) . . mds.	40·74	33·48
	(b) Juice extracted per 100 cane (average for season) . . mds.	64·66	56·52



Sugar drying in the sun.

CHAPTER III.

General working results.

Cane variety. The bulk of cane used for these tests was of the Co. 213 variety, only a small portion towards the close of the season being Co. 290 with sometimes a little indigenous "Dhaul" cane. As a result of tests carried out by the Department of Agriculture, Bhopal, on the comparative merits of different varieties of canes for the Open Pan system of sugar manufacture, Co. 213, though quite good for making *gur*, was found unsuitable for sugar manufacture and its cultivation was eventually abandoned there. The following extract from the Report of the Department of Agriculture, Bhopal State, for 1928-29 (Para. 30) is of interest:—

> "The varieties H. M. 600, Waxy Red, Manjav, Java, B. 1528, and D. 109 in the Manjri series, Ashy Mauritius, Desi Paunda and P. O. J. 33 in the second series of thick canes, and Co. 244, Co. 281 and Co. 290 in the third series of Coimbatore seedlings yield juices of very high purity with low percentages of reducing sugar in most cases. So they boil into massecuites of high quality free from viscosity which are easy to deal with in the centrifugal, and the final recovery of sugar from them is high. The best second sugars, equal to first sugars in appearance, were from Manjav, Java and B. 1528 in the Manjri series and from Co. 281, Co. 290 and Co. 244 in the Coimbatore series.
>
> Of the rest, Co. 213 produces first sugar with a pale yellow tinge, which however yields to treatment and bleaching and when crushed would pass as a superior grade of khand: but it cannot compare with the seedlings above mentioned. Co. 205 is still worse as it produces a yellow sugar which will not yield to treatment. But it has many good points in other respects. It grows well with very little manure or irrigation, it yields a satisfactory ratoon crop in similar circumstances, and the natural colouring matter in its juice, which is objectionable for the manufacturer of white sugar, imparts an attractive appearance to the *gur* made from it. Also it may prove itself a suitable cane for dry cultivation in the moister parts of Central India. The Sugarcane Expert to the Government of India considers it "the poor man's cane" and it is said to have been aodpted in various parts of the Punjab.
>
> The lowest in the scale were Pundia and Cavengerie. As noted in paragraph 26 both proved particularly susceptible to frost and Pundia was quite immature in January. This probably accounts for its results, as in the Bombay Presidency it is regarded as one of the best canes. Cavengerie, on the other hand, has proved there also to be one of the poorest of the Manjri canes both in sucrose content and quality of its *gur*."

The reason for the sugar from Co. 213 being of poor colour appears to lie in the presence in its juice of unusually large

quantities of colouring matter possibly anthocyan. The process of clarification in the Bhopal and Rohilkhand systems is not so perfect as to remove this colouring matter as effectively as in modern factories, where Co. 213 canes do not give any trouble.

For the Khandsari process, Co. 290 and Co. 244 amongst the Coimbatore varieties have been found to be superior to Co. 213. But the crop of Co. 290 grown at Bilari appeared to have been over manured, and did not contain as high a percentage of sucrose as it should have done. There is need for a systematic study of the manuring of Coimbatore canes in order to determine the quantity and kind of manure which would produce in the cane a maximum percentage of sucrose and a minimum of glucose, without materially affecting the tonnage. High tonnage is not the sole desideratum, because when the juice contains an excess of glucose (due to excessive vegetative growth), the quality as well as the yield of sugar are always low, however efficient the boiling may be.

Cane crushing. Nominally the cane crushing season lasted from the 20th January to the 31st March or 71 days, but there were so many interruptions that actually crushing was done for only 39 days. The stoppages of work, amounting in the aggregate to 32 days, were due to the following causes:—

	Days.
(*a*) Bad weather	21
(*b*) Shortage of fuel or cane (due to bad weather)	2
(*c*) Breakdown of cane mills	5
(*d*) Festivals	4
TOTAL	32

The working period was spread over the three months as follows:—

	Days.
January	7
February	7
March	25
TOTAL	39

The total quantity of cane crushed was 13,742·15 mds. In order to ensure that juice supplied to the two experimental *bels* was of the same quality, cane for both *bels* was crushed in the same mill. Juice was sent to the *bels* in tins and it was arranged that a certain number of tins of juice (five or ten) was supplied alternately to each *bel*. As the weighing machines were not sufficient for weighing the juice, arrangements were made for measuring it. (See Appendix B, page 127 for details of the system followed). In this way the quantity of juice supplied separately to the two *bels* each day was determined. As the extraction of juice per 100 cane was calculated daily, the quantity of cane used for each *bel* was found out by calculation. The total figures for the whole season

for cane crushed and juice extracted, calculated in this manner. are as follows:—

	Bhopal	*Rohilkhand*
Cane crushed, maunds . . .	5,925·54	7,816·61
Juice extracted, maunds . .	3,788·29	5,031·01
Extraction (per 100 cane) . .	63·94	64·36

The slight difference in the two figures for extraction is due to the fact that for the first four days only one *bel* was worked each day. The cane mills were being tested during this period to determine their capacity, in order to organise the work and the quantity of cane crushed was therefore not sufficient to feed both *bels*.

The Massey Mill was worked for 32 days, during which period it crushed 11,831·87 mds. of cane in 292·33 hours, giving an average crushing capacity of 40·74 mds. cane per hour. The total quantity of juice extracted by this mill was 7,650·43 mds., thus giving an average extraction of 64·66 per cent. The working of this mill was not found very satisfactory, the main defect being—

(*a*) The mill is not built sufficiently strong and there were several breakdowns, the most serious being the breaking of the top roller shaft.

(*b*) No feed shoot is provided, nor are directions given for fitting one at site. In the absence of a proper feeding arrangement, the feed is uneven resulting both in a lowering of the capacity and efficiency.

(*c*) The top roller of the mill is unflanged and the crushing near the ends of the roller is therefore of poor quality.

(*d*) The belt pulley on the mill has a peripheral speed of 864 feet per minute. This is too low and there is consequently a tendency for the belt to slip even under slight overloads.*

The Chatanooga Mill used was about five years old and was a good deal the worse for wear. It worked for only two days after which it had to be stopped owing to breakage of teeth of gear wheels. Even after repairs it was not brought into use as the extraction of juice was very poor. In all this mill worked for 21·51 hours, and crushed 720·20 mds. cane yielding 407·07 mds. juice. The crushing capacity therefore was 33·48 mds. cane per hour and extraction 56·52 per cent. juice on cane.

Juice boiling. Out of the 39 days on which cane was crushed the Bhopal *bel* worked for 37 days and the Rohilkhand *bel* for 36 days, the total number of hours worked being 432·09 and 458·57 respectively. On an average the Bhopal *bel* worked for 11·67 hours per day and the Rohilkhand *bel* for 12·74 hours.

The average juice boiling capacities of the two *bels*, calculated on the basis of the total quantity of juice boiled in the season, are 8·76 and 10·97 maunds of juice per hour respectively or 105·12 and

* The Massey cane mill used in these tests was an old model, borrowed from the Department of Agriculture. The models made by this firm now are free from most of the defects referred to here.

131·64 maunds respectively for a 12-hour day. Figures for capacities calculated in terms of cane treated and rab produced in each *bel* are given in Table XIII.

TABLE XIII.

Average working capacities of Bhopal and Rohilkhand bels for juice boiling.

Particulars	*Bhopal*	*Rohilkhand*
1. *Bel* worked, days . . .	37	36
2. *Bel* worked, hours . .	432·09	458·57
3. *Bel* worked, hours per day (average)	11·67	12·74
4. Juice boiled, maunds . .	3,788·29	5,031·01
5. I Rab produced, maunds .	802·75	1,020·57
6. Capacity in terms of cane—		
(*a*) Cane per hour, maunds .	13·7	17·0
(*b*) Cane per day of 12 hours, maunds	164·4	204·0
7. Capacity in terms of juice—		
(*a*) Juice per hour, maunds .	8·76	10·97
(*b*) Juice per day of 12 hours, maunds . .	105·12	131·64
8. Capacity in terms of I *Rab*—		
(*a*) I *Rab* per hour, maunds	1·86	2·23
(*b*) I *Rab* per day of 12 hours, maunds . .	22·32	26·76

NOTE. The experimental Bhopal *bel* (consisting of 11 pans) was out of action for 2 days, when another Bhopal *bel* consisting of 10 pans was used. The figures in the column under "Bhopal" given in the above statement include those for the 10-pan *bel* for 2 days. The quantity of juice treated in the 10-pan *bel* was so small that no material difference is caused by combining the figures in this way. Taken separately, the figures for the 10-pan *bel* are as follows:—

Bel worked for 2 days or 22·49 hours and boiled 160·24 mds. of juice, giving a boiling capacity of 7·13 mds. juice per hour.

The Bhopal *bel* was designed for a capacity of 100 maunds juice per day of 12 hours, and actually it treated, on an average 105·12 maunds juice per day, that is, it was worked throughout the season at slightly above its normal capacity. The Rohilkhand *bel* dealt with 131·64 maunds juice per 12 hours, which was not above its normal capacity. It is not clear why more juice was treated in the latter *bel*, because from the figures for cane crushing capacity of the Massey Mill (which worked most of the time) it is evident that more juice was produced daily than the two experimental *bels* put together were able to take up, the surplus having been consequently supplied to the non-experimental *bel*. If the operatives on the Rohilkhand *bel* had exerted themselves more and full quantity of juice had been treated in it, not only would the cost of production have been lower, but, on account of more rapid boiling, the recovery of sugar may also have been increased. This is a point which deserves the attention of those using Rohilkhand *bels* on a commercial basis. It would be worth their while even to put on an extra man on the *bel*, if by doing so they can work it to its full capacity.

That it should have been possible to deal with more juice in the Rohilkhand *bel* was shown by two tests which were carried out for determining the fuel consumption and maximum juice boiling capacities of the two *bels*. The question of fuel consumption will be dealt with later on, but the results obtained in connection with the maximum capacity may be considered here.

In the first test equal quantities of juice (115·92 maunds) were supplied to both *bels* and the boiling was conducted as rapidly as each *bel* permitted. The figures for the test are given in Table XIV. The maximum capacity was found to be 10·70 and 13·70 maunds of juice per hour for the Bhopal and Rohilkhand *bels* respectively or 128·4 and 164·4 maunds per 12-hour day.

In the second test both *bels* were worked for approximately the same period (about 13 hours), boiling being, as before, conducted as rapidly as each *bel* permitted. Unfortunately, during this test an arch of the Bhopal *bel* supporting the Parchhas collapsed. This was due to the fire having been made too strong, with the object of increasing the capacity of the *bel*. The rate of boiling in this *bel* had to be reduced after this accident and hence the figure for capacity is low. The figure obtained in the first test may be accepted for this also.

These high capacities are partly due to the tests having been conducted towards the close of the season, when the juice was of high brix. The analysis of juice given in Table XIV confirms this.

TABLE XIV.

Tests for determining maximum capacity of Bhopal and Rohilkhand bels.

Particulars	*Bhopal*	*Rohilkhand*
A. *First Test on 21st March 1931*—		
In this test equal quantities of juice were supplied to both *bels*, boiling being conducted as rapidly as each *bel* permitted.		
(*a*) Juice boiled, maunds . .	115·92	115·92
(*b*) Time taken for boiling, hours .	10·83	8·45
(*c*) Juice boiled per hour, maunds .	10·70	13·70
(*d*) Juice boiling capacity per 12 hours, maunds . . .	128·40	164·40
B. *Second Test on 22nd March 1931*—		
In this test both *bels* were worked for approximately the same period (about 13 hours), boiling being conducted as rapidly as each *bel* permitted.		
(*a*) Juice boiled, maunds .. .	131·10	178·42
(*b*) Time taken for boiling, hours .	13·16	13·0[illegible]
(*c*) Juice boiled per hour, maunds	9·96	13·73
(*d*) Juice boiling capacity per 12 hours, maunds . .	119·52	164·76

(**NOTE.** During the second test an arch of the Bhopal *bel* supporting the parchhas collapsed. This was due to the fire having been made too strong

with the object of increasing the capacity of the *bel*. The rate of boiling this *bel* had to be reduced after this. Hence the low figures for capacity.)

	First Test	Second Test
C. *Analysis of juice (for both bels)*—		
Brix	19·17	19·35
Sucrose	15·92	16·00
Purity	83·07	82·69
Invert Sugar	0·80	1·21

	Bhopal	Rohilkhand
D. *Analysis of rab (composite for the week)*—		
Brix	89·52	89·37
Sucrose	68·80	67·20
Purity	76·85	75·19
Invert sugar	8·93	9·36

Reverting to the question of the average working capacities of the two *bels,* and comparing these with the figures for maximum capacity obtained in the above tests, the following comparative figures are given:—

	Bhopal	Rohilkhand
(*a*) Average capacity (maunds juice per 12 hours)	105·12	131·64
(*b*) Maximum capacity (maunds juice per 12 hours)	128·4	164·4
(*c*) Difference	23·28	32·76

As regards the yields of *rab* by the two processes, the average figures for the entire season are as follows:—

	Bhopal	Rohilkhand
I *Rab* per 100 cane	13·54	13·05
I *Rab* per 100 juice	21·1	20·27

The Rohilkhand *bel rab* was thicker than that of Bhopal *bel,* the brix being 89·02° and 87·93° respectively. This will account for about 0·2 out of the difference of 0·83 per cent. (on the basis of 100 juice). But a higher brix is not necessarily an advantage from the point of view of recovery of sugar. The first sugar recovered from the Bhopal and Rohilkhand first *rabs* was 44·12 and 39·82 respectively per 100 *rab*.

Molasses boiling. The total quantity of molasses (with wash water) boiled in the Bhopal and Rohilkhand *bels* during the season was 446·93 maunds and 629·12 maunds respectively. Calculated as a percentage on the first *rab* of each process from which this molasses was obtained, the figures are 55·85 and 61·64 per cent. respectively. The reasons for this difference are, firstly, the better boiling and crystallization of the Bhopal *rab*, resulting in the production of more sugar and less molasses, secondly, the smaller quantity of wash water used in machining the Bhopal *rab*, owing to its better quality and thirdly, the insufficient washing of the Bhopal sugar leaving some molasses adhering to the crystals, which, though increasing the yield of sugar, lowers its quality.

The quantity of second *rab* obtained from the above molasses was 361·41 maunds and 495·63 maunds respectively, or 9·6 and 3·85 respectively per 100 juice. But though the yield of Rohilkhand II rab was more than that of Bhopal *rab*, the recovery of sugar

was more from the latter, the figures being 1·98 and 2·79 respectively per 100 juice. At the same time the sugar from the Bhopal *rab* was of a better quality.

There is no doubt that in respect of producing second sugar the Rohilkhand system is at a considerable disadvantage. The principal defects in this process have already been pointed out in Chapter II and it is a comparatively simple matter to rectify these.

Clarifying agents used. The quantities of the different defecants used during the season were as follows:—

Material.	*Bhopal.*	*Rohilkhand.*
	Seers.	Seers.
1. Castor seed	56·87	76·0
2. Sajji	37·37	49·5
3. Deula, Bhindi and Falsa bark .	65·12	88·5
4. Lime	10·0	...
5. Stannous chloride	½	...
Calculated in seers per 100 maunds juice		
1. Castor seed	1·5	1·51
2. Sajji	0·99	0·98
3. Deula, etc.	1·72	1·75

Centrifugalling. In order to determine the capacity of the centrifugal machines under average working conditions, a few tests were carried out. The figures are given in Table XV. Second *rab*, made by the Bhopal process, and of good average quality, was used for the test.

TABLE XV.

Test to determine the capacity of centrifugal machines (Bhopal process II rab was used).

Particulars	Average	Test No. I	Test No. II	Test No. III	Test No. IV
1. Weight of *rab* . . . . lbs.	49·88	50	49·88	49·63	50
2. Weight of moist sugar . lbs.	15·82	15·5	14·25	16·88	16·63
3. Moisture per cent. sugar . .	2·36	2·86	2·86	2·10	1·6
4. Water used for spraying . lbs.	·72	·72	·72	·72	·72
5. Time for slow running, minutes .	2	2	2	2	2
6. Time (from start) when water sprayed, minutes.	4·5	5	4	4	5
7 Total time (from start) for centrifugalling, minutes.	12·5	12·5	12	12	13·5
8. Total time (from start) for complete cycle of operations, minutes	22·9	22·5	25	24	20
9. Output moist sugar per cent. *rab* .	31·7	..	..	..	..
10. Water used for spraying per 100 *rab*.	1·45	..	..	..	..
11. Calculated capacity, maunds *rab* per 12 hours.	19	..	..	..	..
12. Practical capacity, at 80 per cent. of calculated capacity, maunds *rab* per 12 hours.	15·2	..	..	..	..

When the machine is started, it is kept running below the normal speed till part of the molasses has been removed. This is judged from the viscosity of the molasses coming out. The time required for this preliminary operation was found to be two minutes. Four to five minutes after the machine comes to full speed water is sprayed, one syringe of water (about 325 c.cs.) being used. In another five minutes the sugar is finished and is ready for dropping. After the sugar is dropped, the lining of the centrifugal is washed by pouring into the basket about a gallon of hot water. The machine is then ready for charging again.

The total time required for the complete cycle of operations from the time of starting till the machine is again charged and ready for starting is about 23 minutes for each charge of about 50 lbs. *rab*. This gives a theoretical capacity of 19 maunds *rab* per day of 12 hours, or allowing 80 per cent. of this capacity in practice, the machine can deal with 15 maunds of second *rab* per day of 12 hours.

With first *rab*, there is an increase of about 30 to 40 per cent. in the capacity.

Yield of sugar and molasses. The working figures for the entire season, in respect of the output of the principal products, may be summarized as follows:—

	Bhopal	*Rohilkhand*
(*a*) Per 100 cane—		
Juice	63·94	64·36
I *Rab*	13·54	13·05
II *Rab*	6·09	6·34
SUGAR—		
First	5·97	5·20
Second	1·78	1·27
Total	7·76	6·47
Final molasses	3·98	4·70
(*b*) Per 100 Juice—		
I *Rab*	21·1	20·27
II *Rab*	9·6	9·85
SUGAR—		
First	9·35	8·08
Second	2·79	1·98
Total	12·14	10·07
Final molasses	6·23	7·33

More detailed figures are given in the tables of Chemical Control Data in Chapter V.

Comparison with indigenous Khandsaris. The advocates of the Bhopal process are constantly drawing attention to the fact that the Rohilkhand process adopted at Bilari was not the process as commonly followed by the indigenous khandsaris and that it had incorporated several improvements borrowed from the Bhopal process. It is alleged that the recovery of sugar obtained by the Rohilkhand process at Bilari is, in consequence of these improvements, higher than what it ordinarily is in Rohilkhand. In

corroboration of this, it is pointed out that the Indian Sugar Committee, 1920, in its report (paragraph 278) says:—

> "On the basis of the extraction we have mentioned above, this is equivalent to 11 maunds of *rab* to 100 maunds of cane. The wastefulness and inefficiency of the process are sufficiently demonstrated by its net result, which is 4 per cent. of sugar only as against 9·5 per cent. which we estimate as possible in a thoroughly efficient factory."

The supporters of the claims of the Bhopal process also refer to the following sentence which occurs on page 49 of the Report of the Department of Agriculture, United Provinces, for the year ending 30th June 1928:—

> "The growth of better quality canes, namely, canes containing a higher percentage of juice and available sugar, has put the manufacturer of sugar by the indigenous process in a stronger position to meet competition by increasing the outturn of sugar obtained per 100 sugarcane from 3½ to just over 5."

It is stated on behalf of the Bhopal process that the above reference contains the officially recognized recovery from the improved canes under the *bel*-centrifugal system and that the recovery under the Bhopal system, with the same canes was a good deal more. In other words, an attempt is made to prove that the recovery of 7·76 per cent. obtained at Bilari by the Bhopal process is to be compared with this officially recognized recovery of 5 per cent. from the Rohilkhand process and not with 6·47 per cent., the figure actually obtained.

It is not the purpose of this report to support or controvert the claims of the protagonists of any particular process. The object rather is to collect and collate definite data and to draw only such inferences as these data will permit.

In order to obtain information regarding the working figures of ordinary indigenous Khandsaris, an enquiry was made locally. There are many old-established Khandsaris in the vicinity of Bilari and one of these, situated in Bichaula about two miles from the Nagalia Farm, was selected at random for this enquiry. The writer visited the Bichaula Farm on the 26th March 1931 in company with Mr. Krishna Sahai Gupta. No previous intimation of the visit was given either to Mr. Gupta or to Maulvi Afzal Ahmad, the proprietor of the farm.

The cane grown on the farm was found to be almost all of Co. 213 variety but the crop was not good. There appeared to be insufficient manuring and lack of irrigation, which resulted in stunted growth.

The cane was crushed in a Massey Mill with rollers 8 in. by 8 in. driven by an oil engine. The rollers were much worn and there were practically no grooves left on them. The mill was also running at a high speed. The crushing was consequently of poor quality although the quantity of cane put through was large. The extraction of juice was said to be 58 per cent.

For boiling the juice there were two Rohilkhand *bels* of which only one was in use. The *bels* were of a type similar to the one used in Bilari, with only this difference that the large Hauz pan was not fitted and the *bels* consequently consisted of only four pans each. The reason given for this change was that as cane was crushed by the Khandsari himself (instead of the common practice of purchasing juice from the cane growers) there was no necessity for the large pan which is meant only for storage of juice. Not only is the cost of the pan saved in this way, but deterioration of juice by prolonged storage is also avoided.

The four pans composing each *bel* were very similar in shape and size to the pans used at Bilari. The manner of setting up the pans on the furnace also appeared to be substantially the same. The method of working the *bel* and clarifying the *bel* also showed no difference. For aerating the *rab*, there were two earthen tubs for each *bel*. After aerating, the *rab* was put into Kalsis (earthen pots) for cooling and crystallization. The reasons given for not using tins for this purpose were, firstly, the high initial cost of tins and secondly, the better crystallization owing to slower cooling which takes place in Kalsis. For curing the *rab*, the Khanchi system as well as centrifugal machines were used. The molasses boiling *bel* was under construction at the time of the visit. Presumably no second *rab* had been made till then.

The proprietor of the farm was good enough to supply from his books the following figures for recovery of *rab* and sugar:—

(*a*) Yield of I *rab*—10 to 11 local maunds of I *rab* is produced per karda of juice,*

(*b*) Yield of I Sugar—4 to $4\frac{1}{2}$ local maunds of I sugar is produced per karda of juice,

(*c*) Machining—In machining 26 to 27 seers of *rab* is put into the machines per charge, and $11\frac{1}{2}$ to 12 seers of sugar is obtained after drying.

These figures, after conversion into standard weight, have been entered in the form of a comparative statement in Table XVI.

TABLE XVI.

Statement showing figures obtained from Bichaula Farm, as compared with those of Bilari (for Bhopal and Rohilkhand processes).

Particulars	Bichaula. 58 per cent. extraction (actual)	Bichaula. 64 per cent. extraction calculated	Bhopal	Rohilkhand
A. Per 100 Cane—				
Juice	58·00	64·00	63·94	64·36
I *Rab*	12·18	13·54	13·54	13·05
I Sugar	4·93	5·64	5·97	5·20
B. Per 100 Juice—				
I *Rab*	21	...	21·1	20·27
I Sugar	8·5	...	9·35	8·08
C. Per 100 I Rab—				
I Sugar	44·3	...	44·12	39·82

*1 Local maund = 1·25 Standard maund of 82·3 lbs.
1 Karda = 50 local maunds = 62·5 standard maunds.

Corresponding figures for the Bhopal and Rohilkhand processes are also given in the table. It will be observed from this statement that the Bichaula figures are all superior to those of the Rohilkhand process at Bilari, and in several important items are only slightly below those of the Bhopal process. It cannot, therefore, be said that the efficiency of the Rohilkhand process, as worked at Bilari, was high because it had incorporated improvements copied from the Bhopal process, or that the efficiency of all Rohilkhand type of Khandsaris is always lower than that of the Bhopal process.

It was unfortunate that second sugar had not been produced at Bichaula till the date of the visit. This fact renders the comparison incomplete as it is in making the second sugar that most of the difference in efficiency takes place.

Comparison with Indian factories. The working figures (average for a complete season) for an Indian factory working by the sulphitation process are given in Table XVII.

TABLE XVII.

Working figures.

Whole season's average for a sulphitation factory of moderate efficiency.

Particulars	*Data*
1. *Analysis of Cane*—	
Sucrose	12·13
Fibre	15·00
2. *Juice Extraction*—	
Dilute juice per 100 cane	86·20
Added water per 100 cane	18·95
Undiluted juice per 100 cane	67·25
3. *Yields per 100 cane*—	
Wet Bagasse	32·75
I & II Sugar	9·21
Final Molasses	3·58
4. *Yields per 100 Juice* (undiluted)—	
I & II Sugar	13·69
Final Molasses	5·32
5. *Efficiency—Cane crushing*—	
Sucrose in juice per cent. sucrose in cane	86·15
6. *Efficiency—Boiling House*—	
Sucrose in sugars per cent. sucrose in juice	86·79
7. *Overall Efficiency*—	
Sucrose in sugars per cent. sucrose in cane	74·78

It is observed from these figures that working with a cane containing a lower percentage of sugar and extracting 67·25 per cent. juice a recovery of 9·23 per cent. sugar on cane is obtained. The overall efficiency is 74·78 per cent. as against 55·06 and 46·85 per cent. respectively for the Bhopal and Rohilkhand processes.

CHAPTER IV.

Comparative Costs of the Two Processes.

Capital Cost. In comparing the capital costs of the two processes, it is not necessary to take into consideration those items which are common. Thus the Cane Mills, Engine, Pugmills and Centrifugal machines are common to both processes and may be omitted in the comparison. All that it is necessary to compare is the initial costs of the Bhopal and Rohilkhand *bels* for boiling first and second *rabs*.

As regards the construction of the two types of furnaces, there is no standard design for the Rohilkhand type. The juice boiler engaged for the season builds this according to his own ideas, and usually different men have different ways of doing this. But in the case of the Bhopal *bel*, an attempt has been made to standardise the furnace and it is built according to definite dimensions. A mason, working under the directions of the juice boiler is required for the purpose, as, unlike the Rohilkhand *bel*, a fair amount of brickwork has to be made. The Rohilkhand furnace is usually built by the Jhonkas (firemen) under the supervision of the juice-boiler. These men are engaged on contract for the whole season and building the furnace is part of their work under the contract. For this reason the cost of the Rohilkhand furnace does not amount to more than Rs. 30. As against this the cost of the Bhopal furnace (together with a small thatched store room), as actually built at Bilari was Rs. 135 including Rs. 26-10-9, the wages of a boiler from Bhopal. Allowing Rs. 50 for the store room, the cost of the furnace itself is Rs. 85.

It should, however, be pointed out that the Bhopal furnace is of a more durable construction and is likely to last, with some petty annual repairs, for two or three years, whilst the Rohilkhand furnace has to be re-built every year. Moreover a Khandsari cannot, as a rule, afford to build a furnace of a permanent nature in any village as he is never sure of being able to carry on his business in the same village year after year. It is only a zemindar or the owner of a farm, with his own assured supply of cane, who can go to the expense of constructing a masonry furnace of a durable type.

The cost of the pans used in the Bhopal system is lower than that of the much larger sized pans used in a Rohilkhand *bel*. The two sets of pans used for these experiments cost Rs. 325 and Rs. 500 respectively. One season's experience is insufficient for determining the durability of the pans. The flat bottomed pans of the Bhopal *bel* are made of 1/16″ sheet, the bottom plate being $\frac{5}{8}$″ thick. These are exceptionally heavy and should last for many years.

The total cost of the two *bels* may, therefore, be stated as follows:—

	Bhopal Rs.	Rohilkhand Rs.
(*a*) Cost of furnace	85	30
(*b*) Cost of pans	325	500
Total cost of *Bel* .	410	530

Labour requirements of the two processes. The labour actually employed during the tests was as follows:—

(*a*) *Cane Crushing* (Common to both processes)—	
(*i*) Engine—	
Mechanic	1
Water and coal man	1
(*ii*) Cane Mills—	
Oilman	1
Cane feeders	2
For removing bagasse	1
Spare man	1
For carrying juice	3
For carrying bagasse (work done by Jhonkas) .	2
Total .	12
(*b*) *Juice Boiling*—	
(*i*) Rohilkhand *bel*—	
Karigar (boiling foreman) (on contract)	1
Nikharas (clarification men)	3
Jhonkas (firemen). They also attend to drying of bagasse, carrying dried bagasse, feeding furnace and doing other sundry work (on contract) . .	5
Total .	9
(*ii*) Bhopal *bel*—	
Karigar	1
Nikharas	3
Jhonkas	5
Extra labour	2
Total .	11
(*c*) *Molasses Boiling*—	
(*i*) Rohilkhand *bel*—	
Karigar	1
Jhonka	1
Labourers	2
Total .	4
(*ii*) Bhopal *bel*—	
Karigar (on contract)	1
Jhonka	1
Labourers	2
Total .	4

(*d*) *Centrifugal machines* (common to both processes)—

Mechanic	1
Centrifugal attendant	1
Pugmill man	1
Total	3

In addition sundry labour was provided as required.

(*e*) *Sugar Drying* (common to both processes)—

Generally two men were employed over each Patta, but the number varied according to the quantity of sugar to be dried and also depended on the weather. If sufficient sugar was available for drying, up to four men per Patta were required.

Financial aspect of the Experiments. From a financial point of view, the results of the experiments may be considered under the following heads—

(*a*) Expenditure,
(*b*) Receipts,
(*c*) Profit,
(*d*) Cost of production.

Each of these items is discussed in detail in the following paragraphs.

Expenditure. (*a*) *Salaries and Wages.* The expenditure incurred on salaries and wages is shown in Table XVIII. Some of the men are, according to custom, paid lump sums on a contract basis. Under this category come the juice boilers and Nikharas (clarification men). It is also usual to give them food and to provide them with a few other facilities. These have, however, not been taken into account in the statement.

The Supervising staff, consisting of four Munshis (clerks), was common to the two processes and hence the salary of these men has been divided equally between the two. The cane crushing staff was also common, as cane was crushed at one place and juice supplied to both the *bels*. The wages of the cane crushing men have been divided between the two processes in proportion to the quantity of juice treated by each.

The wages of men employed in the Bhopal process for boiling juice and molasses and working Centrifugal machines are high as specially trained men were brought from Bhopal. It is possible to train local men for the work on a lower scale of wages. The Bhopal *bel* for juice boiling is, however, more expensive to work than the Rohilkhand *bel*, as it needs more men to attend to the much larger number of pans. As the juice boiling capacity of the former *bel* is smaller, the labour cost for the same quantity of juice treated becomes still higher.

The statement in Table XVIII shows actual as well as normal expenditure. For cane crushing and work under the Rohilkhand process, the expenditure actually incurred was on the usual commercial scale and hence there is no difference between "actual" and "normal" figures. For the Bhopal process there is, however, an appreciable difference between the two, due, as explained above, to the higher scale of wages paid to men from Bhopal,

TABLE XVIII.

Statement of Expenditure under Salaries and Wages.

Particulars.	Common to both Rohilkhand and Bhopal						Bhopal						Rohilkhand						Remarks
	Actual			Normal			Actual			Normal			Actual			Normal			
	No.	Rate	Amount	No.	Rate	Amount	No.	Rate	Amount	No.	Rate	Amount	No.	Rate	Amount	No.	Rate	Amount	
		Rs.	Rs. A. P.		Rs.	Rs. A. P.		Rs.	Rs. A. P.			Rs. A. P.			Rs. A. P.			Rs. A. P.	
Supervising Staff.																			
Munshis	4	15	180 0 0	..	..	180 0 0	..	..	..	..	..	..	..	..	..	..	..	..	
Proportion charged to each process.	..	..	..	..	..	..	..	..	90 0 0	..	..	90 0 0	..	..	90 0 0	..	..	90 0 0	
Cane Crushing.																			
Mechanic	1	40	84 9 0	..	..	84 9 0	..	..	..	..	..	..	..	..	..	..	..	..	
Water & Coal man	1	..	23 11 6	..	..	23 11 6	..	..	..	..	..	..	..	..	..	..	..	..	
Crusher men	4	As. 4 per day.	51 7 10	..	..	51 7 10	..	..	..	..	..	..	..	..	..	..	..	..	
Weighing men	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
Juice suppliers	3	..	25 15 0	..	..	25 15 0	..	..	..	..	..	..	..	..	..	..	..	..	
TOTAL	..	..	185 11 4	..	..	185 11 4	..	..	..	..	..	..	..	..	..	..	..	..	
Proportion charged to each process.	..	..	..	..	..	..	..	..	79 5 9	..	..	79 5 9	..	..	106 2 1	..	..	106 2 1	
Juice Boiling.																			
Boiler	..	..	..	..	..	..	1	40	93 5 3	1	..	55 0 0	1	Contract	73 6 0	1		146 11 0	Economy possible under normal conditions by training local labour.
Nikharas	..	..	..	..	..	..	3	..	58 8 0	3	..	58 8 0	3	,,		3			
Jhonkas	..	..	..	..	..	..	5	..	55 0 0	5	..	55 0 0	5	..	73 5 0	5			
Extra labour	..	..	..	..	..	..	2	As. 4 per day	19 0 0	2	..	19 0 0	..	..	..	..	..	..	
TOTAL	..	..	..	..	..	..	..	..	225 13 3	..	..	187 8 0	..	..	146 11 0	..	..	146 11 0	
Molasses Boiling.																			
Boiler	..	..	..	..	..	..	1	40	94 10 8	1	..	45 0 0	1	As. 4 per day	37 12 0	1		37 12 0	Ditto.
Feeder	..	..	..	..	..	..	1	..	..	1		33 0 0	1			1			
Labour for sundry work.	..	..	..	..	..	..	2	As. 4 per day.	33 0 0	2		..	2			2			
TOTAL	..	..	..	..	..	..	..	..	127 10 8	..	..	78 0 0	..	..	37 12 0	..	..	37 12 0	
Centrifugalling.																			
Driver	..	..	..	..	..	..	1	30	41 0 0	..	..	..	1	30	40 0 0	..	..	..	
Centrifuger	..	..	..	..	..	..	1	25	67 8 0	..	..	162 8 0	..	..	76 4 0	..	..		
Labour for sundry work.	..	..	..	..	..	..	..	..	54 0 0	..	..	..	..	..		..	..	116 4 0	
TOTAL	..	..	..	..	..	..	..	..	162 8 0	..	..	162 8 0	..	..	116 4 0	..	..	116 4 0	
Drying, weighing, etc., of sugar.	..	..	..	..	..	..	..	..	35 14 0	..	..	35 14 0	..	As. 4 per day	48 10 0	..	..	48 10 0	
TOTAL	..	..	..	..	..	..	..	..	721 3 8	..	..	633 3 0	..	..	545 7 1	..	..	545 7 1	

TABLE XIX.

Statement showing Expenditure Excluding Salaries and Wages.

Serial No.	Particulars	Common Actual	Common Normal	Bhopal Actual	Bhopal Normal	Rohilkhand Actual	Rohilkhand Normal
1	*Cane Crushing*—						
	Cost of Coal	299 13 6	260 0 0	..	..	..	..
	Cost of lubricants	37 9 4	35 0 0	..	..	..	..
	Rent, freight, cartage, etc. of Crusher	169 9 5	169 9 5	..	..	..	..
	Repairs to crusher	119 8 0	119 8 0	..	..	..	..
	TOTAL	626 8 3	584 1 5	..	..	..	..
	Proportion charged to each process	..	..	268 8 0	250 5 0	358 0 3	333 12 5
2	*Juice Boiling*—						
	Cost of fuel	..	..	66 5 3	33 2 8	88 1 9	44 0 10
	Cost of defecants	..	..	52 4 4	52 4 4	69 11 3	69 11 3
3	*Molasses Boiling*—						
	Cost of fuel	..	..	30 8 0	30 8 0	42 15 0	42 15 0
4	*Potting Rab*—						
	Cost of tins (proportionate depreciation)	..	..	166 11 0	112 8 0	217 5 0	150 0 0
5	*Centrifugalling*—						
	Cost of oil, petrol and sundry stores	..	..	104 2 4	104 2 4	146 15 8	146 15 8
6	*Depreciation* of Machinery at 10 per cent.	..	..	108 8 6	108 8 6	141 7 6	141 7 6
7	*Depreciation* of Boiling Plant at 10 per cent.	..	..	32 8 0	32 8 0	50 0 0	50 0 0
	TOTAL	..	..	829 7 5	723 14 0	1,114 8 5	975 14 4

(*b*) *Other expenditure* (*excluding salaries and wages*). Other items of expenditure, like cost of fuel, clarifying material, tins, oil, etc., and depreciation at 10 per cent. on machinery and boiling pans are shown in Table XIX. The figures for total expenditure (that is, including salaries and wages) are given in Table XX. The cost of crushing 13,743·57 maunds cane (for both the processes) comes to Rs. 626-8-3 *plus* Rs. 185-11-4 for wages or 11·35 pies per maund. This is higher than usual. As there was a steam engine available at site, this was used for driving the Cane Mill, coal being used as fuel. Coal is expensive in these parts. A crude oil engine, or better still, an electric motor worked by current from the hydro-electric system, would have been cheaper. The steam engine used was of 30 H.P., whilst the cane mills took only about 18 H.P. This further increased the cost.

TABLE XX.

Statement showing total Expenditure including cost of Cane.

Serial No.	Particulars	Bhopal System		Rohilkhand System	
		Actual	Normal	Actual	Normal
		Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
1	Supervising Staff	90 0 0	90 0 0	90 0 0	90 0 0
2	Cane Crushing	347 13 9	329 10 9	464 2 4	439 14 0
3	Juice Boiling	344 6 10	272 15 0	304 8 0	260 7 1
4	Molasses Boiling	158 2 8	108 8 0	80 11 0	80 11 0
5	Potting of rabs	166 11 0	122 8 0	217 5 0	150 0 0
6	Centrifugalling	266 10 4	266 10 4	304 8 0	260 7 1
7	Drying, Weighing, etc. of sugar	35 14 0	35 14 0	48 10 0	48 10 0
8	Depreciation of Machinery	108 8 6	108 8 6	141 7 6	141 7 6
9	Depreciation of Boiling Plant	32 8 0	32 8 0	50 0 0	50 0 0
10	Miscellaneous	30 12 0	30 12 0	30 12 0	30 12 0
	Total	1,581 7 1	1,397 14 3	1,690 11 6	1,555 1 5
	Cost of cane at As. 6 per Std. Md.	2,222 8 9	2,222 8 9	2,931 4 3	2,931 4 3
	Grand Total	3,803 15 10	3,620 6 3	4,621 15 9	4,486 5 8

With cane at six annas per maund and juice extraction of 63·91 per cent. and 64·36 per cent. respectively for the Bhopal and Rohilkhand processes, the cost of juice comes to Rs. 42-2-5 and

Rs. 42-7-2 per Karda, or say an average of Rs. 42-4. For purposes of comparison, enquiries were made locally for the current rate of juice. It was ascertained that three zemindars in the vicinity sold their juice at Rs. 48, Rs. 45 and Rs. 44 per Karda respectively, giving an average of Rs. 45-11. It would appear therefore that even though the crushing charges for the tests were high and the extraction of juice was not particularly good (with efficient mills this should be about 68 per cent.), the juice supplied to the experimental bels was cheaper than the current market rate by Rs. 3-7 per karda. Due allowance should be made for this in the figures for cost of production of sugar which are given later on.

For boiling juice to first *rab*, a large quantity of fuel in addition to the bagasse obtained from the cane crushed, was used. This consisted of bagasse purchased from other neighbouring khandsaris, cane trash and dry leaves of trees. The total cost of this extra fuel was Rs. 230-11-6. The fuel was burnt in both the experimental *bels* and also in another Rohilkhand *bel* which was worked non-experimentally. It was not possible to keep a record of the quantity burnt in each *bel* separately, but it could be seen in a general way that all the three *bels* were taking extra fuel. For allocating the cost of additional fuel to the Bhopal and Rohilkhand *bels* an arbitrary basis has therefore been adopted. Out of the total sum of Rs. 230-11-6, a third (*viz.*, Rs. 76-4-6) has been charged to the non-experimental *bel* and the balance of Rs. 154-7 has been distributed between the two experimental *bels* in proportion to the quantities of juice boiled in each. The cost of extra fuel for the Bhopal and Rohilkhand *bels* calculated in this way comes to Rs. 66-5-3 and Rs. 88-1-9 respectively. For the normal figures, half these amounts are taken, as the *bels* can be worked longer under non-experimental conditions.

For boiling molasses to second *rab*, both *bels* used outside fuel and the cost of this is shown in the statement (Table XIX). No reduction in these figures is anticipated under normal non-experimental conditions.

For potting *rab* empty kerosene oil tins were used. The life of these tins has been assumed to be two seasons, and cost of tins required has been calculated accordingly. For "normal" figures, half the cost of tins with which a khandsari can deal with the *rab* resulting from the quantity of juice treated, has been taken as the basis.

Depreciation on juice boiling pans and machinery has been allowed at 10 per cent. No depreciation has been allowed on buildings, furnace, and other masonry work nor has any allowance been made for interest on working capital or remuneration of the Manager or Proprietor.

In addition to the items covered by Table XX, further expenditure amounting in the aggregate to Rs. 395-6 was incurred, but this was of such a nature that it had to be excluded from the cost

accounts of these experiments. Particulars of this expenditure are given in the statement in Table XXI.

TABLE XXI.

Statement showing certain Items of Expenditure actually incurred but not included in the cost of manufacture.

	Rs.	A.
1. Pay of Chowkidars	72	0
2. Pay of a man employed for sampling juice and counting tins of juice supplied to the *bels* .	45	0
3. Labour employed for weighing cane . . .	40	14
4. Munshi for taking weight of cane . . .	60	0
5. Pay of store-keeper		
6. Bhopal Centrifuger—Pay for January . .	25	0
7. Bhopal Boiler—Pay for January (for boiling molasses)	40	0
8. Bhopal Mechanic—Pay for January . . .	30	0
9. Bhopal Oilman—Pay for January . . .	15	0
Total	395	6

This includes wages paid to watchmen and to men employed for sampling juice, counting tins, weighing cane and doing other similar work in connection with the chemical control. As chemical control is never adopted in a khandsari, it will be incorrect to charge these items of expenditure to the cost of production of sugar. Another item of expenditure which had to be left out of the account of the experiments is the wages paid to four workmen from Bhopal during the month of January, when the commencement of the experiments was delayed owing to late arrival of some of the equipment.

Receipts. The receipts from the sale of sugar and molasses by the two processes are shown in Table XXII. The molasses produced by both processes fetched the same price—*viz.*, Rs. 1-8 per standard maund. The sugars, however, were of different qualities and fetched different prices. The first sugar of the Bhopal process was inferior to the Rohilkhand first sugar, but the second sugar of the former process was better in appearance than that of the latter. As the quantity of first sugar is proportionately much larger than that of the second, the average price for the total quantity of sugar produced by the two processes was Rs. 9-5-6 per standard

maund for the Rohilkhand process and Rs. 9-1-9 for the Bhopal process.

TABLE XXII.

Statement showing Income obtained by Rohilkhand and Bhopal Processes.

Serial No.	BHOPAL SYSTEM		ROHILKHAND SYSTEM	
	Particulars	Amount	Particulars	Amount
		Rs. A. P.		Rs. A. P.
1	Price of sugar I at Rs. 34-8 per Palla (3 local Mds.) equivalent to Rs. 9-3-3 per Std. Md.	3,258 13 0	Price of sugar I at Rs. 36 per Palla (or Rs. 9-9-7 per Std. Md.)	3,903 13 5
2	Price of Sugar II at Rs. 33 per Palla (or Rs. 8-12-9 per Std. Md.)	929 4 6	Price of Sugar II at Rs. 32 per Palla (or Rs. 8-8-6 per Std. Md.)	849 9 4
3	Price of final molasses at Rs. 1-8 per Std. Md.	353 13 7	Price of final molasses at Rs. 1-8 per Std. Md.	553 10 4
	TOTAL .	4,541 15 1	....	5,307 1 1

Profits. The working profit under the two systems is obtained by deducting the total expenditure from the total sale proceeds of sugar and molasses. Figures for this are shown in Table XXIII. The total quantity of juice treated was 60·6 kardas by the Bhopal system and 80·5 kardas by the other system. These are within the limits of the usual capacity of an average khandsari. The profit calculated per karda of juice (which is the basis of calculation amongst khandsaris) is higher for the Bhopal process than for the Rohilkhand process by Rs. 3·7 per karda actual and Rs. 3·1 per karda normal, that is, by 43·5 per cent. and 30·4 per cent. respectively.

TABLE XXIII.

Statement showing Working Profits.

Particulars	BHOPAL SYSTEM		ROHILKHAND SYSTEM	
	Actual	Normal	Actual	Normal
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Total incomes from Sugars and Molasses.	4,541 15 1	4,541 15 1	5,307 1 1	5,307 1 1
Total expenditure including price of cane.	3,803 15 10	3,620 6 3	4,621 15 9	4,486 5 8
Net Profit .	737 15 3	921 8 10	685 1 4	820 11 5
Weight of juice treated (Kardas) .	60·6	60·6	80·5	80·5
Net profit per Karda of juice .	12·2	15·3	8·5	10·2

The total profit under the Bhopal system amounts to Rs. 737-15-3 and under the Rohilkhand system to Rs. 685-1-4. Considering

that nothing has been provided for the remuneration of the proprietor or for interest on the money invested by him, the business cannot be regarded as particularly lucrative.

Cost of Production. The cost of production of one maund of sugar is calculated by deducting the sale proceeds of molasses from the total expenditure (including the cost of cane) and dividing the balance by the weight of sugar produced. The cost of sugar, calculated in this manner, under the two systems and under actual and normal conditions is shown in Table XXIV. The cost per maund, under actual experimental conditions is Rs. 7-8 for Bhopal process and Rs. 8-0-5 for Rohilkhand process, and under normal conditions Rs. 7-1-7 and Rs. 7-12-2 respectively.

TABLE XXIV.

Statement showing cost per maund of sugar.

Particulars	Bhopal System		Rohilkhand System	
	Actual	Normal	Actual	Normal
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Total cost of production . .	3,803 15 10	3,620 6 3	4,621 15 9	4,486 5 8
Deduct price of Final molasses . .	353 13 7	353 13 7	553 10 4	553 10 4
Net expenses .	3,450 2 3	3,266 8 8	4,068 5 5	3,932 11 4
Total sugar produced . . .	459·81 Mds.	459·81 Mds.	506·5 Mds.	506·5 Mds.
Cost of sugar per Std. Md. . .	Rs. 7 8 0	Rs. 7 1 7	Rs. 8 0 5	Rs. 7 12 2

A detailed analysis of the cost of production is given in Table XXV. In this table the cost for each sub-head is shown per maund of sugar. It will be observed from these figures that the expenses per maund of sugar for the two processes are approximately the same, being Rs. 3-6-11 for the Bhopal process and Rs. 3-5-4 for Rohilkhand actuals, and Rs. 3-0-6 and Rs. 3-1-1 normals. The difference in the total cost of production of sugar is due mainly to the difference in the cost of raw material (cane) per maund of sugar, which in turn is a result of the difference in the recovery of sugar per cent. cane between the two processes. In other words, this means that from the point of view of the total working expenses the two processes are on an approximately equal footing, the advantage in favour of the Bhopal process being due only to the higher yield of sugar.

TABLE XXV.

Analysis of cost of production per maund of sugar.

Items of Cost	Bhopal		Rohilkhand	
	Actual	Normal	Actual	Normal
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
A. *Expenses*—				
1. Supervising Staff	0 3 1	0 3 1	0 2 10	0 2 10
2. Cane Crushing	0 12 2	0 11 6	0 14 8	0 13 11
3. Juice boiling	0 12 0	0 9 6	0 9 7	0 8 3
4. Molasses boiling	0 5 6	0 3 9	0 2 7	0 2 7
5. Potting Rab	0 5 9	0 4 3	0 6 11	0 4 9
6. Centrifugalling	0 9 3	0 9 3	0 8 4	0 8 4
7. Drying, Weighing, etc., of sugar	0 1 2	0 1 2	0 1 6	0 1 6
8. Depreciation of machinery	0 3 9	0 3 9	0 4 5	0 4 5
9. Depreciating of Boiling plant	0 1 2	0 1 2	0 1 7	0 1 7
10. Miscellaneous	0 1 1	0 1 1	0 0 11	0 0 11
TOTAL	3 6 11	3 0 6	3 5 4	3 1 1
B. *Raw material*—				
Cost of cane at 6 as. per md.	4 13 5	4 13 5	5 12 7	5 12 7
TOTAL	8 4 4	7 13 11	9 1 11	8 13 8
Deduct price of Molasses at Rs. 1-8 per md.	0 12 4	0 12 4	1 1 6	1 1 6
Net cost of 1 Md. Sugar	7 8 0	7 1 7	8 0 5	7 12 2

It should be pointed out, however, that the total working expenses, in respect of which the two processes have been shown to be equally good, include several items which have no direct connection with the efficiency of the processes under test. Items 1, 2, 8, 9 and 10 in Table XXV fall under this category and should not be taken into account in comparing the economic aspect of the two processes. For this purpose the expenses on juice boiling, molasses boiling, potting *rab*, centrifugalling and drying and weighing of sugar (that is, items 3, 4, 5, 6 and 7 of Table XXV) should only be taken into consideration. The totals for these items amount to Rs. 2-1-8 per maund of sugar for the Bhopal system and Rs. 1-10-11 for Rohilkhand, actuals, and Rs. 1-11-11 and Rs. 1-9-5 respectively, normals. The Rohilkhand system is therefore at a distinct advantage from the point of view of the working costs.

Cost figures for individual manufacturing operations in the two processes have been worked out separately and are shown in Table XXVI. These comprise the cost of crushing one maund cane (which is common to both processes), of boiling 100 maunds juice to first *rab*, of boiling 100 maunds molasses to second *rab*, and of drying, weighing, etc., one maund of sugar. These figures show that the Bhopal process is approximately 50 per cent. more expensive than the Rohilkhand process in boiling juice to *rab* and the cost of boiling molasses to second *rab* in the former is two to three times of that in the latter process.

TABLE XXVI.

Cost figures for individual operations in the two processes.

Particulars	Bhopal		Rohilkhand	
	Actual	Normal	Actual	Normal
1. Cost of crushing cane (pies per md. of cane)	11·27	10·68	11·40	10·8
2. Cost of boiling juice to I *Rab* (Rs. per 100 Mds. juice).	9·09	7·20	6·05	5·17
3. Cost of boiling Molasses to II *Rab* (Rs. per 100 mds. dilute molasses).	35·39	22·04	12·82	12·82
4. Cost of machining I and II *Rab* (annas per md. of *rab*).	3·66	3·66	2·77	2·77
5. Cost of drying, weighing, etc. of I and II Sugar (annas per md. of sugar).	1·16	1·16	1·53	1·53

It would appear therefore, that whilst the Bhopal process gives a higher yield of sugar, there is still considerable scope for lowering the working costs.

Before leaving the subject of costs of production, reference may be made to Table XXVII in which figures for an average Indian factory have been given for comparison. These are based on information contained in the Report of the Indian Tariff Board on the Sugar Industry, which has recently been published.

TABLE XXVII.

Cost of production per maund of sugar in an average Indian factory.

	Rs.	A.	P.
1. Cane at As. 6 per maund	4	2	7
2. Other raw materials (including sulphur, filter cloth, etc.)	0	2	0
3. Labour	0	8	0
4. Power and fuel	0	1	3
5. Supervision, office charges, etc. (including pay and travelling allowance of European and Indian Supervising and Technical staffs, head office expenses, clerical establishment, Directors' and Auditors' fees, etc.) . .	0	11	
6. Current repairs	0	7	
7. Packing	0	2	
8. Depreciation	0	8	
9. Miscellaneous (including Managing Agents' commission at 7½ per cent. on profit) . .	0	10	0
Total .	7	4	10
Deduct for Molasses at Rs. 1-8 per maund at 4 per cent. on cane	0	10	8
Net cost per maund of sugar	6	10	2

NOTES.

(*i*) This statement is based on figures given in Chapter V of the Report of the Indian Tariff Board on the Sugar Industry.

(*ii*) The price of cane usually paid by the factories is about As. 8 per maund (including delivery charges), but as a price of As. 6 has been allowed for cane at Bilari, the above statement has also been based on this price.

(*iii*) The above figures are for a factory crushing 13,00,000 maunds of cane per season and yielding 9 per cent. sugar and 4 per cent. molasses.

(*iv*) Interest on working capital has usually to be paid by factories, but it has not been allowed in the above statement, as no provision for this has been made in the costs at Bilari.

(*v*) Item No. 5 (supervision and office charges) includes salaries of Manager and other expert staff. Nothing has been provided in Bilari costs for these. An allowance of As. 4 to 6 per maund will be necessary for this difference.

CHAPTER V.

Chemical Control Data.

System of Chemical Control. The system of chemical control which was prescribed in connection with these experiments is described in detail in Appendix B. Briefly, this contains instructions regarding the methods to be adopted for determining quantities, for sampling and analysing and for maintaining the laboratory records.

The methods of sampling and analysis adopted at Bhopal during the tests of February and March 1930 differ slightly from those adopted at Bilari. As these differences have an effect on the analytical data obtained in the two tests, a note indicating the differences is given at the end of Appendix B.

Chemical Control Data. Daily and Weekly analytical and control figures were systematically recorded throughout the season in accordance with the prescribed system. It is not necessary, nor is it possible, for want of space, to reproduce these figures in full here. Tables XXVIII to XXXVI contain totals and averages of the more important items, for each week as well as for the entire season, as per particulars given below:—

(*a*) Weekly average figures for analysis of materials for Bhopal process (Table XXVIII) and Rohilkhand process (Table XXIX).

(*b*) Weekly average figures for quantities of materials and yield percentages—for Bhopal process (Table XXX) and Rohilkhand process (Table XXXI).

(*c*) Analysis figures—whole season's averages for the two processes (Table XXXII).

(*d*) Quantities and yields of material—whole season's averages for the two processes (Table XXXIII).

(*e*) Account of sucrose recovered and lost—whole season's averages for the two processes (Table XXXIV).

(*f*) Brix account—whole season's averages for the two processes (Table XXXV).

(*g*) Invert Sugar account—whole season's averages for the two processes (Table XXXVI).

The tables are self-explanatory and hence a detailed discussion of the chemical control data is not called for. Only the more salient features of these are dealt with in the following paragraphs.

Cane. The cane crushed was of good quality throughout as compared with the canes which Indian sugar factories have to deal with. The sucrose content varied between 11·49 and 14·30 per cent., whilst fibre was between 13·61 and 15·46 per cent. (excluding one doubtful figure of 11·19 per cent. fibre). The average for the season was 13·33 per cent. sucrose and 13·88 per cent. fibre.

TABLE XXVIII.

Bhopal Process.—Weekly average figures for analysis of materials.

Serial No.	Particulars of Analysis	Average for the season	Figures for week ending 25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
1	*Cane*—															
	(*a*) Sucrose . . per cent	13·33	..	12·25	11·49	..	..	13·25	13·67	13·17	13·39	14·06	14·30	..	..	..
	(*b*) Fibre . . ,,	13·88	..	15·46	14·72	..	..	13·87	11·19	13·61	14·09	14·41	13·62	..	..	..
2	*Bagasse*—															
	(*a*) Sucrose . . ,,	8·35	..	7·79	7·61	..	..	8·06	9·37	8·18	8·54	8·49	8·53	..	..	..
	(*b*) Moisture . . ,,	51·02	..	48·47	56·55	..	..	54·14	57·58	51·50	48·25	46·77	49·84	..	..	..
3	*Juice*—															
	(*a*) Sucrose . . ,,	16·08	15·17	14·82	14·61	..	..	16·42	16·02	15·88	15·91	16·89	17·28	..	..	..
	(*b*) Brix . . ,,	19·08	17·83	17·61	17·68	..	..	18·51	18·53	18·87	19·42	20·22	20·52	..	..	..
	(*c*) Purity . . ,,	84·35	87·31	84·18	82·63	..	..	88·69	86·42	84·16	81·91	83·53	84·21	..	..	..
	(*d*) Invert Sugar . ,,	1·10	0·93	1·15	1·21	..	..	0·55	0·74	0·81	1·34	1·16	1·25	..	..	..
4	*I Rab*—															
	(*a*) Sucrose . . ,,	69·83	70·6	70·0	65·6	..	..	70·00	70·00	70·00	68·80	70·8	72·0	..	..	..
	(*b*) Brix . . ,,	87·93	83·52	84·25	83·41	..	..	88·26	88·10	86·89	89·52	90·17	89·32	..	..	..
	(*c*) Purity . . ,,	79·42	84·52	83·09	78·65	..	..	79·31	79·46	80·56	76·85	78·52	80·61	..	..	..
	(*d*) Invert Sugar . ,,	7·81	7·28	7·53	9·72	..	..	6·86	6·29	6·62	8·93	8·73	7·38	..	..	..
5	*II Rab*—															
	(*a*) Sucrose . . ,,	52·63	..	..	50·4	..	..	52·00	54·2	53·4	52·4	51·2	52·00	55·6	..	..

TABLE XXVIII—(concld.)

Bhopal Process.—Weekly average figures for analysis of materials.

Serial No.	Particulars of Analysis	Average for the season	FIGURES FOR WEEK ENDING 25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
5	*II Rab*—contd.															
	(b) Brix . . per cent.	90·59	..	..	85·05	..	..	88·82	88·26	92·19	93·72	92·54	91·48	91·42	..	..
	(c) Purity . . ,,	58·10	..	..	59·26	..	..	58·55	61·41	57·92	55·91	55·33	56·84	60·81	..	..
	(d) Invert Sugar . ,,	16·74	..	..	15·36	..	..	17·45	13·71	15·36	15·36	19·20	18·29	16·34	..	..
6	*I Molasses* (diluted)—															
	(a) Sucrose . . ,,	44·20	..	..	42·65	..	..	42·32	44·84	44·69	45·59	41·64	44·91	46·90	..	..
	(b) Brix . . ,,	74·08	..	..	70·71	..	..	71·61	71·43	74·19	76·01	75·43	75·89	75·18	..	..
	(c) Purity . . ,,	59·67	..	..	60·31	..	..	59·09	62·77	60·23	59·98	55·20	63·40	62·39	..	..
	(d) Invert Sugar . ,,	13·21	..	..	12·27	..	..	13·09	11·05	11·99	12·24	15·99	13·90	13·11	..	..
7	*Final Molasses*—															
	(a) Sucrose . . ,,	33·64	..	..	..	..	..	34·0	..	32·80	..	36·40	39·0	33·2	33·80	33·00
	(b) Brix . . ,,	85·69	..	..	..	..	..	81·51	..	83·53	..	86·69	88·65	86·41	85·85	86·19
	(c) Purity . . ,,	39·26	..	..	..	..	..	41·71	..	39·27	..	41·99	44·00	38·42	38·21	38·29
	(d) Invert Sugar . ,,	23·38	..	..	..	..	..	21·33	..	24·0	..	21·33	20·21	22·58	23·99	25·60
8	*First Sugar*—															
	(a) Sucrose . . ,,	96·4	..	..	95·2	..	..	96·0	96·0	97·4	96·2	96·6	96·7	97·6	..	..
	(b) Moisture . . ,,	0·51	..	..	1·2	..	..	0·50	0·40	0·50	0·30	0·30	0·50	0·40	..	..
9	*Second Sugar*—															
	(a) Sucrose . . ,,	95·2	..	..	..	..	..	97·0	..	96·2	96·0	96·0	96·4	96·0	94·6	93·6
	(b) Moisture . . ,,	0·66	..	..	..	..	..	0·8	..	0·50	1·20	0·40	0·4	0·5	0·6	0·9
10	*Scum*—															
	Sucrose . . ,,	14·10	14·32	14·16	13·99	..	..	11·33	15·12	15·34	13·75	12·51	14·16	..	..	..

TABLE XXIX.

Rohilkhand Process.—Weekly average figures for analysis of materials.

Serial No.	Particulars of Analysis		Average for the season	Figures for week ending													
				25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
1	*Cane—*																
	(a) Sucrose	Per cent	13·37	..	12·25	11·49	..	..	13·25	13·67	13·17	13·39	14·06	14·30	..	..	..
	(b) Fibre	,,	13·88	..	15·46	14·72	..	..	13·87	11·19	13·61	14·09	14·41	13·62	..	..	..
2	*Bagasse—*																
	(a) Sucrose	,,	8·35	..	7·79	7·61	..	..	8·06	9·37	8·18	8·54	8·49	8·53	..	..	..
	(b) Moisture	,,	51·02	..	48·47	56·55	..	..	54·14	57·58	51·50	48·25	46·77	49·84	..	..	..
3	*Juice—*																
	(a) Sucrose	,,	16·08	15·57	14·82	14·61	..	..	16·42	16·02	15·88	15·91	16·89	17·28	..	..	..
	(b) Brix	,,	19·08	17·83	17·61	17·68	..	..	18·51	18·53	18·87	19·42	20·22	20·52	..	..	..
	(c) Purity	,,	84·31	87·31	84·18	82·63	..	..	88·69	86·42	84·16	81·91	83·53	84·21	..	..	..
	(d) Invert Sugar	,,	1·01	0·93	1·15	1·21	..	..	0·55	0·74	0·81	1·34	1·16	1·25	..	..	..
4	*I Rab—*																
	(a) Sucrose	,,	69·59	69·13	67·20	67·80	..	..	70·40	70·40	70·20	67·20	71·40	71·60	..	..	..
	(b) Brix	,,	89·02	83·99	86·33	84·73	..	..	88·82	86·33	89·14	89·37	90·97	90·72	..	..	..
	(c) Purity	,,	78·17	82·41	77·84	80·02	..	..	79·26	81·55	78·76	75·19	78·78	78·92	..	..	..
	(d) Invert Sugar	,,	8·22	8·19	9·36	9·84	..	..	7·38	6·29	6·98	9·36	9·14	7·76	..	..	..
5	*II Rab—*																
	(a) Sucrose	,,	59·57	..	..	51·0	44·0	..	49·2	53·20	52·40	48·8	39·8	50·8	50·4	..	..
	(b) Brix	,,	90·06	..	..	86·96	85·05	..	90·83	89·39	89·38	90·74	91·54	90·98	90·01	..	..
	(c) Purity	,,	66·15	..	..	58·64	51·74	..	54·17	59·52	58·63	53·78	43·48	55·83	55·91	..	..
	(d) Invert Sugar	,,	18·70	..	..	18·28	19·20	..	20·75	16·00	15·06	19·20	20·21	19·45	20·21	..	..

TABLE XXIX—(concld.)

Rohilkhand Process.—Weekly average figures for analysis of materials.

Serial No.	Particulars of Analysis	Average for the season	Figures for week ending													
			25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
6	*I Molasses* (diluted)—															
	(a) Sucrose . . per cent.	43·48	..	..	42·52	39·0	..	39·86	45·04	43·63	44·63	42·35	42·97	45·20	..	..
	(b) Brix . . ,,	74·51	..	..	71·84	74·04	..	69·41	73·29	73·06	77·13	75·09	74·95	76·14	..	..
	(c) Purity . . ,,	58·35	..	..	59·19	52·67	..	57·44	61·45	59·72	57·86	56·40	57·34	59·37	..	..
	(d) Invert Sugar . ,,	14·02	..	..	13·63	15·36	..	14·05	12·35	12·54	13·74	14·94	14·84	14·85	..	..
7	*Final Molasses*—															
	(a) Sucrose . ,,	33·14	..	..	..	..	..	..	31·00	27·60	34·40	36·00	35·20	34·0	32·0	35·0
	(b) Brix . . ,,	83·83	..	..	..	..	..	..	80·89	68·55	85·42	84·88	80·95	85·85	85·44	84·77
	(c) Purity . . ,,	39·53	..	..	..	..	..	..	38·32	40·26	40·27	42·41	43·48	49·61	37·45	41·29
	(d) Invert Sugar . ,,	23·06	..	..	..	..	..	..	23·99	19·69	21·33	21·33	20·21	22·58	23·27	25·60
8	*I Sugar*—															
	(a) Sucrose . . ,,	97·02	..	..	97·60	97·0	..	97·20	97·0	96·8	96·2	97·0	96·60	98·0	..	..
	(b) Moisture . . ,,	0·38	..	..	0·44	0·80	..	0·25	0·40	0·50	0·30	0·60	0·40	0·20	..	..
9	*II Sugar*—															
	(a) Sucrose . . ,,	95·46	..	..	..	..	..	..	96·40	95·00	95·60	96·20	94·20	93·20	95·20	95·0
	(b) Moisture . . ,,	0·57	..	..	..	..	..	..	0·60	0·40	0·40	0·45	0·50	1·0	0·60	0·40
10	*Scum*—															
	Sucrose . . ,,	15·08	13·06	14·5	14·70	..	..	14·20	15·79	16·22	15·05	15·16	15·05	..	..	..

TABLE XXX.

Bhopal Process.—Weekly quantities and yield percentages.

Serial No.	Particulars	Average and total for the season	Figures for week ending 25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
1	*Quantities—*															
	(a) Cane . . . Mds.	5,925·54	361·61	453·10	359·55	..	..	839·31	461·06	902·02	1,133·71	1,105·43	309·75	..	..	..
	(b) Juice . . . „	3,788·29	211·75	886·06	203·20	..	..	520·24	298·36	582·54	746·60	735·27	204·27	..	..	..
	(c) I *Rab* . . . „	802·75	44·86	57·72	43·60	..	..	107·73	59·88	120·84	160·15	162·62	45·35	..	..	..
	(d) II *Rab* . . „	361·41	..	..	26·76	..	..	36·91	59·07	25·53	28·08	55·14	91·73	38·19	..	..
	(e) I Sugar . . . „	354·23	..	..	32·09	..	..	32·78	57·22	25·92	28·69	52·82	82·62	42·09	..	..
	(f) II Sugar . . . „	105·60	..	..	..	..	..	6·58	..	7·09	3·49	14·69	3·10	15·64	36·29	18·72
	(g) Total Sugar . . „	459·83	..	..	32·09	..	..	39·36	57·22	33·01	32·18	67·51	85·72	57·73	36·29	18·72
	(h) I Molasses (diluted) „	446·93	..	..	34·14	..	..	45·30	72·66	31·35	34·22	69·34	112·63	47·29	..	..
	(i) Final Molasses . . „	235·90	..	..	..	..	..	18·80	..	17·03	8·05	29·59	6·65	34·40	82·72	38·66
	(j) Scum . . . „	89·33	4·89	5·86	2·93	..	..	8·12	6·35	12·06	21·75	21·58	5·79	..	..	..
2	*Efficiency—Cane Crushing—*															
	(a) Juice per cent. cane .	63·93	58·56	63·14	56·51	..	..	61·98	64·71	64·58	65·86	66·52	65·95	..	..	
	(b) Sucrose in juice per cent. sucrose in cane.	77·68	..	76·91	72·29	..	..	76·83	75·88	78·09	78·22	79·44	79·60	..	..	..

TABLE XXX—(*concld.*)

Bhopal Process.—Weekly quantities and yield percentages.

Serial No.	Particulars	Average and total for the season	Figures for week ending													
			25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
3	*Efficiency—Juice Boiling—*															
	(*a*) I *Rab* per cent. cane	13·53	12·41	12·74	12·13	..	..	12·84	12·99	13·40	14·13	14·71	14·60	..	..	..
	(*b*) I *Rab* per cent. juice	21·19	21·19	20·18	21·46	..	..	20·71	20·07	20·74	21·45	22·12	22·20	..	..	..
	(*c*) Sucrose in I *Rab* per cent. sucrose in juice.	91·86	93·73	94·17	96·33	..	..	88·32	87·90	91·45	92·70	92·72	92·57	..	..	..
4	*Efficiency—Molasses Boiling—*															
	(*a*) II *Rab* per cent. I Molasses.	80·96	..	..	78·38	..	..	81·48	81·30	81·44	82·06	79·52	81·44	80·76	..	..
	(*b*) Sucrose in II *Rab* per cent. sucrose in I Molasses.	96·40	..	..	90·54	..	..	100·10	98·28	97·29	94·30	97·86	94·31	95·72	..	..
5	*Efficiency—I Sugar Curing and Drying—*															
	(*a*) I Sugar per cent. I *Rab*	44·11	..	..	47·27	..	..	41·87	44·01	44·67	46·20	44·18	42·30	45·99	..	..
	(*b*) Sucrose in I Sugar per cent. sucrose in I *Rab*.	61·03	..	..	63·92	..	..	59·50	60·35	62·15	63·49	61·68	58·45	65·10	..	..
6	*Efficiency—II Sugar Curing and Drying—*															
	(*a*) II Sugar per cent. II *Rab*	29·90	..	..	..	..	..	24·59	..	28·10	29·88	30·32	29·19	29·19	29·28	30·63
	(*b*) Sucrose in II Sugar per cent. sucrose in II *Rab*.	51·94	..	..	..	..	..	47·39	..	52·00	55·16	53·70	51·90	52·98	53·63	52·70

TABLE XXXI.

Rohilkhand Process.—Weekly quantities and yield percentages.

Serial No.	Particulars	Average and total for the season	Figures for week ending 25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
1	*Quantities*—															
	(*a*) Cane . . . Mds.	7,816·61	534·71	430·03	360·90	..	..	1,146·12	723·94	1,247·03	1,604·78	1,315·10	454·00	..	..	..
	(*b*) Juice . . . ,,	5,031·01	338·97	272·52	203·87	..	..	711·97	468·13	806·36	1,056·69	873·04	299·46	..	..	..
	(*c*) I *Rab* . . . ,,	1,020·57	66·37	52·03	41·67	..	..	142·96	93·32	163·45	216·79	181·73	62·25	..	..	..
	(*d*) II *Rab* . . ,,	495·63	..	..	29·33	13·25	..	33·07	39·05	74·74	77·93	48·79	92·55	86·92	..	..
	(*e*) I Sugar . . ,,	406·49	..	..	27·17	10·89	..	25·44	35·78	7·09	7·07	36·52	74·37	76·16	..	..
	(*f*) II Sugar . . ,,	99·88	..	..	..	..	..	..	1·95	6·31	7·19	6·55	2·94	14·20	37·28	23·46
	(*g*) Total Sugar . ,,	506·37	..	..	27·17	10·89	..	25·44	37·73	13·40	14·26	43·07	77·31	90·36	37·28	23·46
	(*h*) I Molasses (diluted) ,,	629·12	..	..	38·38	16·69	..	42·62	47·54	96·67	98·63	61·18	117·66	109·70	..	..
	(*i*) Final Molasses . ,,	368·12	..	..	..	..	..	..	6·08	27·50	35·85	21·90	10·75	44·73	138·52	82·79
	(*j*) Scum . . . ,,	120·78	6·05	5·15	3·40	..	..	13·8	10·26	18·25	30·57	24·86	8·44	..	..	..
2	*Efficiency—Cane Crushing*—															
	(*a*) Juice per cent. cane .	64·36	63·43	63·35	56·50	..	..	62·00	64·67	64·66	65·85	66·39	65·96	..	..	..
	(*b*) Sucrose in juice per cent. sucrose in cane.	77·78	..	76·26	71·43	..	..	76·85	75·72	77·98	78·22	80·05	79·74	..	..	..
3	*Efficiency—Juice Boiling*—															
	(*a*) I *Rab* per cent. cane .	13·06	12·41	12·08	11·56	..	..	12·44	12·39	13·11	13·51	13·82	13·71	..	..	..
	(*b*) I *Rab* per cent. juice .	20·29	19·57	19·08	20·47	..	..	20·15	19·93	20·27	20·52	20·82	20·79	..	..	..
	(*c*) Sucrose in I *Rab* per cent. sucrose in juice.	87·78	88·30	87·84	94·83	..	..	86·06	87·51	89·41	86·71	88·03	86·13	..	..	..

TABLE XXXI—*concld.*

Rohilkhand Process.—Weekly quantities and yield percentages.

Serial No.	Particulars	Average and total for the season	FIGURES FOR WEEK ENDING 25/1	1/2	8/2	15/2	22/2	1/3	8/3	15/3	22/3	29/3	5/4	12/4	19/4	26/4
4	*Efficiency—Molasses Boiling—*															
	(a) II *Rab* per cent. I Molasses.	78·78	..	..	77·72	79·39	..	77·59	82·14	77·31	78·97	79·75	78·66	79·23	..	..
	(b) Sucrose in II *Rab* per cent. sucrose in I Molasses.	89·68	..	..	91·67	89·55	..	95·76	97·01	92·84	86·35	74·95	92·98	88·34	..	..
5	*Efficiency—I Sugar Curing and Drying—*															
	(a) I Sugar per cent. I *Rab*	39·83	..	..	40·94	38·58	..	38·81	42·33	39·60	38·84	38·52	39·56	40·74	..	..
	(b) Sucrose in I Sugar per cent. sucrose in I *Rab*.	54·81	..	..	57·80	55·84	..	55·82	58·33	54·44	53·65	54·74	55·80	55·87	..	..
6	*Efficiency—II Sugar Curing and Drying—*															
	(a) II Sugar per cent. II *Rab*	20·15	..	..	..	..	..	..	21·67	18·79	16·45	23·05	21·32	23·33	19·50	20·39
	(b) Sucrose in II Sugar per cent. sucrose in II *Rab*.	38·87	..	..	..	..	..	..	41·21	37·00	31·34	41·68	38·33	41·44	39·35	38·37

Table XXXII.

Analysis figures.—Whole season's average for Bhopal and Rohilkhand processes.

S. No.	Particulars of analysis	Bhopal	Rohilkhand
1.	*Cane*—		
	(a) Sucrose	13·33	13·37
	(b) Fibre	13·88	13·88
2.	*Bagasse*—		
	(a) Sucrose	8·35	8·35
	(b) Moisture	51·02	51·02
3.	*Juice*—		
	(a) Sucrose	16·08	16·08
	(b) Brix	19·08	19·08
	(c) Purity	84·35	84·31
	(d) Invert Sugar	1·10	1·01
4.	*I Rab*—		
	(a) Sucrose	69·83	69·59
	(b) Brix	87·93	89·02
	(c) Purity	79·42	78·17
	(d) Invert Sugar	7·81	8·22
5.	*II Rab*—		
	(a) Sucrose	52·63	59·57
	(b) Brix	90·59	90·06
	(c) Purity	58·10	66·15
	(d) Invert Sugar	16·74	18·70
6.	*I Molasses (diluted)*—		
	(a) Sucrose	44·20	43·48
	(b) Brix	74·08	74·51
	(c) Purity	59·67	58·25
	(d) Invert Sugar	13·21	14·02
7.	*Final Molasses*—		
	(a) Sucrose	33·64	33·14
	(b) Brix	85·69	83·83
	(c) Purity	39·26	39·53
	(d) Invert Sugar	23·38	23·06
8.	*I Sugar*—		
	(a) Sucrose	94·4	97·02
	(b) Moisture	0·51	0·38
9.	*II Sugar*—		
	(a) Sucrose	95·2	95·46
	(b) Moisture	0·66	0·57
10.	*Scum*—		
	Sucrose	14·10	15·08

TABLE XXXIII.

Quantities and yields of materials.—Whole season's averages for Bhopal and Rohilkhand processes.

S. No.	Particulars		Bhopal	Rohilkhand
1.	*Quantity*—			
	(a) Cane	Mds.	5,925·54	7,816·61
	(b) Juice	"	3,788·29	5,031·01
	(c) Wet bagasse (calculated)	"	2,137·25	2,785·60
	(d) Dry bagasse (calculated)	"	1,046·83	1,364·39
	(e) I *Rab*	"	802·75	1,020·57
	(f) II *Rab*	"	361·41	495·63
	(g) I Sugar	"	354·23	406·49
	(h) II Sugar	"	105·60	99·88
	(i) Total Sugar	"	459·83	506·37
	(j) I Molasses (diluted)	"	446·93	629·12
	(k) Final Molasses	"	235·90	368·12
	(l) Scum	"	89·33	120·78
2.	*Yields per 100 Cane*—			
	(a) Juice		63·94	64·36
	(b) Wet bagasse		36·06	35·63
	(c) Dry bagasse		17·66	17·44
	(d) I *Rab*		13·54	13·05
	(e) II *Rab*		6·09	6·34
	(f) I Sugar		5·97	5·20
	(g) II Sugar		1·78	1·27
	(h) Total Sugar		7·76	6·47
	(i) I Molasses (diluted)		7·54	8·04
	(j) Final Molasses		3·98	4·70
	(k) Scum		1·50	1·54
3.	*Yields per 100 Juice*—			
	(a) Wet bagasse		56·41	55·35
	(b) Dry bagasse		27·66	27·1
	(c) I *Rab*		21·1	20·27
	(d) II *Rab*		9·6	9·85
	(e) I Sugar		9·35	8·08
	(f) II Sugar		2·79	1·98
	(g) Total Sugar		12·14	10·07
	(h) I Molasses (diluted)		11·8	12·51
	(i) Final Molasses		6·23	7·33
	(j) Scum		2·36	2·40
4.	*Yields per 100 Rab*—			
	(a) I Sugar % I *Rab*		44·12	39·82
	(b) II Sugar % II *Rab*		29·22	20·15
	(c) I Molasses (diluted) % I *Rab*		55·85	61·64
	(d) Final Molasses % II *Rab*		65·29	74·3
5.	*Efficiency—Cane Crushing*—			
	Sucrose in Juice % sucrose in cane		77·26	77·42
6.	*Efficiency—Juice boiling*—			
	Sucrose in I *Rab* % sucrose in juice		91·86	87·78
7.	*Efficiency—Molasses boiling*—			
	Sucrose in II *Rab* % sucrose in I Molasses		96·40	89·68
8.	*Efficiency—I Sugar Curing & Drying*—			
	Sucrose in I Sugar % sucrose in I *Rab*		61·03	54·81
9.	*Efficiency—II Sugar curing & Drying*—			
	Sucrose in II Sugar % in II *Rab*		51·94	38·87

Bagasse. The sucrose in bagasse was low in the beginning of the season when cane contained less sucrose but gradually increased towards the end of the season. For four weeks the crushing was particularly bad and during this period the moisture in bagasse varied between 51·50 and 57·58 per cent., the sucrose going up to 9·37 per cent. The mill was re-set and the efficiency increased, the moisture in bagasse going down to 46·77 per cent. The average sucrose and moisture content for the season were 8·35 and 51·02 per cent. respectively.

The quantity of bagasse (undried) produced, average for the season, was 36·06 and 35·63 per 100 cane respectively for the Bhopal and Rohilkhand processes. Allowing for the moisture content of 51·02 per cent., the corresponding quantities of dry bagasse are 17·66 and 17·44 per 100 cane. The extraction of juice per 100 cane for the two processes was 63·94 and 64·36. From these figures can be calculated the ratio:—

$$\frac{\text{Weight of juice per 100 cane.}}{\text{Weight of dry bagasse per 100 cane.}}$$

The importance of this juice-bagasse ratio lies in determining whether the bagasse available is sufficient for boiling the concomitant quantity of juice or not. The values of the juice-bagasse ratio (average for the season) for the Bhopal and Rohilkhand processes are 3·62 and 3·69 respectively.

A distinction should, however, be made here between bagasee absolutely free from moisture (as assumed above) and the ordinary sun-dried bagasse as actually burnt. Some fuel tests were made towards the end of the season, the results of which are described in Chapter VI. The moisture content of sun-dried bagasse was determined in connection with these tests and was found to be about 4 per cent. The ratio of juice to sun-dried bagasse calculated on this basis, average for the entire season comes to 3·48 and 3·54 respectively for the Bhopal and Rohilkhand *bels*.

Juice. Excepting when the cane was for some reason not crushed soon after cutting (which happened on several occasions owing to bad weather or shortage of labour), the juice was always of high purity, the highest weekly average being 88·69. The experiments were, in fact, conducted with fully mature cane throughout and due allowance should be made for this fact in considering the high yield of sugar obtained.

The invert sugar content of the juice was unusually high, the average for the season being 1·10 per cent. This is due partly to cane getting stale, but the principal reason appears to be over manuring of the cane. A high invert sugar content is much more detrimental to good recovery of sugar by the open pan process than by the vacuum pan process, as invert sugar is rapidly decomposed at the high temperature to which juice is heated in direct fired pans.

First rab. The average brix of the first *rab* produced by the Bhopal and Rohilkhand processes was 87·93 and 89·02 respectively.

The Rohilkhand *rab* was, in other words, made of a higher concentration. This is not conducive to good crystallisation and is partly responsible for the lower yield of sugar from it. The sugar recovered from Bhopal and Rohilkhand *rabs* amounted to 44·12 and 39·82 per 100 parts of *rab* respectively.

The average purities of the Bhopal and Rohilkhand *rabs* were 79·42 and 78·17 respectively, the drop in purity from juice to *rab* amounting to 4·93 and 6·14 points respectively. This indicates the comparative inefficiency of the Rohilkhand process of clarification and boiling. It may be mentioned that in sugar factories there is always a rise of purity from juice to syrup and massecuite, the exact amount of rise depending on the clarification process adopted and on the extent to which clarification has been effective.

The amount of sugar which can theoretically be recovered from that present in the *rab* depends on the purities of the *rab*, the resulting sugar and the molasses obtained from that *rab*. The available sugar can be computed by the following formula* (in the deduction of which the only postulate required is that there is no loss of brix) :—

$$\text{Available sucrose per cent.} = 100 \times \frac{(j\ m)}{j\,(s-m)}$$

where s, j, and m are purities of sugar, *rab* and molasses respectively.

It is obvious from this formula that a drop in the purity of *rab* lowers the proportion of sugar recoverable from it. In this respect the Rohilkhand *rab* is inferior to the Bhopal *rab*, the latter being however at a considerable disadvantage as compared with a factory massecuite, the purity of which, as explained already, is higher than that of juice.

Reverting to the average figures for analysis of *rab*, it is observed that the Bhopal and Rohilkhand *rabs* contain 7·81 and 8·22 per cent. invert sugar respectively, whilst the invert sugar present in the juice treated by the two processes was 1·10 and 1·01 per cent. respectively. The larger increase in invert sugar in the Rohilkhand *rab* shows that much more inversion takes place in that process as compared with the Bhopal process.

Second rab. The remarks made above regarding first *rab* apply to a great extent also to the second *rab* produced by the two processes. The higher percentage of invert sugar in second *rab* made by the Rohilkhand process again points to more inversion as compared with the Bhopal process.

A noticeable feature of the Rohilkhand second *rab* is its high purity as compared with the purity of the Molasses from which it was boiled and also with the purity of the Bhopal Second *rab*. This shows that the process of clarification adopted in making Rohilkhand second *rab* was superior to that in the Bhopal process. Owing however to defective boiling and the presence of too much invert sugar, the formation of crystals was not satisfactory with the result that in spite of the higher purity of the *rab*, the yield

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* See "Cane Sugar" by Noel Deerr, 1921, page 556.

of second sugar was lower in the Rohilkhand process than in the other one.

First Molasses (diluted). There is no special feature in connection with the first molasses produced by the two processes. The slightly lower purity of the Rohilkhand molasses is due to the higher concentration of the first *rab* from which it is obtained, but this gain is more than counterbalanced by the much larger quantity (12·51 per cent. on juice) of molasses produced as compared with that for the Bhopal process (11·80 per cent. on juice).

Final Molasses. The composition of the final molasses produced by the two processes is also very similar, the average figures for the Bhopal and Rohilkhand processes respectively being 39·26 and 39·53 for purity and 23·38 and 23·06 for invert sugar.

Sugar. The first and second sugars produced by the Bhopal process are both chemically of a lower quality than those made by the other process. This is particularly the case with the first sugar (which forms the major portion of the total output). The percentages of sucrose and moisture (average for the season) in the Bhopal process first sugar are 94·4 and 0·51 as against 97·02 and 0·38 in the Rohilkhand process sugar. The colour of the former sugar (which forms the major portion of the total output. The fetched a lower price. The higher moisture content also involves risk of deterioration of sugar on storage specially during the damp monsoon months. If the Bhopal sugar had been sufficiently washed in the centrifugal for improving its quality to the standard of Rohilkhand sugar, the recovery of sugar would have been reduced by much more than the difference between the polarizations of the two sugars as the loss of crystal sugar by solution is particularly high during the finishing stages of the washing operation. This is a point which has an important bearing on the comparative merits of the Bhopal and Rohilkhand processes of juice boiling, is the additional yield of sugar due to insufficient washing in the centrifugals has nothing to do with the efficiency of the boiling process.

The second sugar made by the Bhopal process was chemically of lower quality to the Rohilkhand sugar, the percentage of sucrose and moisture being 95·2 and 0·66 for the former and 95·46 and 0·57 for the latter. The colour of the Bhopal second sugar was, however, superior to that of the Rohilkhand sugar. The explanation for this anomaly lies in the fact that on account of greater charring during the process of boiling second *rab* by the Rohilkhand process, the molasses adhering to the crystals has a darker colour, so much so that even though a smaller quantity of molasses adheres to the crystals in the case of Rohilkhand sugar (as evidenced by the higher sucrose and lower moisture) the deterioration of colour is more than in the case of the Bhopal second sugar.

Comparing Bhopal second sugar with the first sugar made by the same process it is observed that (contrary to the case of the second and first sugars of the Rohilkhand process) the polarization of the former is higher although the colour is slightly inferior. The explanation for this is similar to that given above for the

difference in colour between the second sugar made by the two processes. The enveloping film of molasses in the case of the Bhopal second sugar, though less in quantity than in the first sugar (as shown by the higher polarization), is of a darker colour owing to more caramelization in boiling second rab.

Scum. The average sucrose content of scum obtained from the juice boiling bels of the Bhopal and Rohilkhand processes was 14·10 and 15·08 per cent. respectively, the corresponding figures for the quantity produced being 2·36 and 2·40 per cent. on juice. In both these respects the Rohilkhand process compares unfavourably with the Bhopal process. If the scum had been washed and allowed to drain more, better results could easily have been obtained.

Efficiency Factors. In Table XXXIII are given, in a comparative form for the two processes, the figures for efficiency for each of the five operations: cane crushing, juice boiling, molasses boiling, first sugar curing and drying and second sugar curing and drying. Excepting for cane crushing (which has no connection with the process under test), the Bhopal process shows higher efficiency throughout.

TABLE XXXIV.

Account of sucrose recovered and lost.—Whole season's averages for Bhopal and Rohilkhand processes.

Particulars	Per 100 sucrose in cane		Per 100 sucrose in juice	
	Bhopal	Rohilkhand	Bhopal	Rohilkhand
A. Sucrose recovered—				
1. In I Sugar . .	42·33	37·73	54·79	48·74
2. In II Sugar .	12·73	9·12	16·47	11·78
Total recovered .	55·06	46·85	71·26	60·52
B. Sucrose lost—				
1. In bagasse .	22·74	22·58	—	—
2. In Scum . .	1·54	1·75	1·99	2·25
3. During boiling juice to 1 *Rab* (excluding loss in Scum) . .	4·74	7·72	6·15	9·97
4. During boiling Molasses to II *Rab* .	0·91	2·70	1·19	3·49
5. During machining and drying I Sugar . .	3·62	4·05	4·69	5·23
6. During machining and drying II Sugar .	1·35	2·68	1·71	3·46
7. In final molasses .	10·04	11·67	13·00	15·08
Total lost .	44·94	53·15	28·74	39·48

TABLE XXXV.

Brix Account.—Whole season's figures for Bhopal and Rohilkhand processes.

Particulars		Bhopal	Rohilkhand
A. Total Brix present in—			
1. Juice	Mds.	722·99	959·71
2. I *Rab*	,,	705·80	908·52
3. II *Rab*	,,	327·39	446·34
4. I Molasses	,,	331·08	468·74
5. Final molasses	,,	202·04	308·60
6. I Sugar	,,	352·42	404·95
7. II Sugar	,,	105·00	99·32

B. Brix recovered—	*Per 100 Brix in juice.*	
1. In I Sugar	48·74	42·19
2. In II Sugar	14·52	10·35
3. In Final molasses	28·02	32·15
Total recovered	91·28	84·69

C. Brix lost—		
1. During boiling juice to I Rab (including loss in scum)	2·39	5·36
2. During boiling molasses to II Rab	0·52	2·33
3. During machining and drying I Sugar	3·00	3·62
4. During machining and drying II Sugar	2·81	4·00
Total lost	8·72	15·31

TABLE XXXVI.

Invert sugar account.—Whole season's figures for Bhopal and Rahilkhand processes.

Particulars		Bhopal	Rohilkh.
A. Invert Sugar present in—			
1. Juice	Mds.	38·27	50·93
2. I *Rab*	,,	62·67	83·98
3. II *Rab*	,,	60·49	92·66
4. I Molasses	,,	59·05	88·22
5. Final Molasses	,,	55·13	84·89
B. Increase of Invert Sugar—			
1. From Juice to I *Rab*	,,	24·40	33·05
2. From I Rab to I Molasses	,,	–3·62	4·24
3. From I Molasses to II *Rab*		1·44	4·41
4. From II *Rab* to Final Molasses	,,	–5·36	–7·77
5. Total increase	,,	16·86	33·96
C. Increase of Invert Sugar per 100 Invert Sugar in juice—			
1. From juice to I *Rab*		63·7	64·91
2. From I Rab to I Molasses		–9·4	8·3
3. From I Molasses to II Rab		3·7	8·7
4. From II *Rab* to II Molasses		–14·0	–15·2
5. Total increase		44·0	66·71

Sucrose Account. Of the total quantity of sucrose present in cane or juice, the proportions which are recovered in first and

second sugars by each of the two processes are shown in Table XXXIV. The losses of sucrose in each of the three bye-products (bagasse, scum and final molasses) as also in the following four main stages of the manufacturing process are also shown in this table:—

(*i*) During boiling juice to I *Rab* (excluding loss in scum);

(*ii*) During boiling molasses to II *Rab;*

(*iii*) During machining and drying I Sugar; and

(*iv*) During machining and drying II Sugar.

The figures for sucrose recovered as well as for the losses are computed, for both processes, per 100 parts of sucrose in cane and also per 100 parts of sucrose in juice.

Comparing the figures for the two processes, the most noticeable feature is that in every item, the recovery of sucrose is less and the losses are more in the case of the Rohilkhand process, thus indicating the higher efficiency of the Bhopal process at every stage. But, whilst this is so, the absolute efficiency of the Bhopal process itself is not very high, as it recovers only 55·06 per cent. of the sucrose in cane and 71·26 per cent. of the sucrose in juice. The losses in boiling juice to I *Rab* and in machining and drying I and II sugars are unquestionably high.

A minor point of technical detail may be mentioned here. In preparing sucrose accounts it is usually found that a small percentage of sucrose is generally left unaccounted for. The sucrose account in Table XXXIV, however, balances perfectly and no unaccounted losses have to be allowed for. The reason for this is that in sugar factory sucrose accounts, the losses of sucrose in bye-products only (*e.g.*, bagasse, press-cake, and molasses) are taken into consideration, whilst in Table XXXIV, in addition to losses in the bye-products, those in different stages of the manufacturing process have also been included. The latter losses in the aggregate correspond to the " unknown loss " of a sugar factory sucrose account.

Brix Account. The purpose of a brix account is to show what proportion of soluble solids (comprising sucrose as well as non-sugars) originally present in juice is recovered in the form of the two grades of sugars and of molasses, and what proportion is lost. In interpreting a brix account certain essential differences from a sucrose account should be kept in mind. Thus if inversion takes place during manufacturing operations, sucrose is converted into invert sugar and a loss of sucrose is indicated in the sucrose account. But no loss of dissolved solids takes place in consequence of this inversion and the brix account should therefore remain unaffected.

Suspended matter, *e.g.*, cush cush, does not affect the brix. Clarification removes some of the dissolved solids, but generally a certain proportion of the clarifying agent (*e.g.*, lime or sajji) enters into solution and causes a corresponding increase of brix.

Losses of brix are mostly due to mechanical loss of material in process. Thus when centrifugal machines are washed after discharging the sugar, the wash water carries away the molasses adhering to the basket and the outer drum, and a loss of brix takes place. Similarly if *rab* is allowed to get overheated to such an extent that some of the sugars and organic matter are burnt off and volatilized, there will be a loss of brix.

The figures for losses of brix in Table XXXV indicate serious mechanical loss (in both the processes) in machining and drying I and II Sugars. This is partly due to the washing of centrifugal machines referred to above. But some loss also takes place owing to spillage of *rab* and molasses. The method of drying sugar in the sun, where it is trampled under feet at a time of the year when there is generally a strong wind, is also responsible for the loss of an appreciable quantity of sugar.

The loss of brix during boiling I and II *rabs* is due to removal of dissolved solids in scum along with suspended impurities and also to charring.

The figures in Table XXXV show that the losses of brix are lower in the Bhopal process than in the Rohilkhand process.

Invert Sugar Account. Starting with the invert sugar originally present in the juice, and determining the invert sugar in the intermediate and finished products, an invert sugar account has been prepared in Table XXXVI, for the purpose of determining the progress of inversion during the manufacturing process. In a well-conducted modern sugar factory inversion losses are usually so small that they are not ordinarily detectable. But in the direct fired open pan system inversion constitutes the most important source of loss of sucrose and hence an invert sugar account is of greater utility as a method of control in this system than in a sugar factory.

Referring to the figures for increase of invert sugar given in Table XXXVI, it is observed that in boiling juice to I *Rab*, the Bhopal and Rohilkhand processes are on approximately the same level, the former process having only a slight advantage over the latter. But in boiling the second *rab* (*i.e.*, in the part of the process from first molasses to second *rab*) the increase of invert sugar under the Bhopal method is 3·7 (per 100 invert sugar in juice) as against 8·7 under the other method. This confirms that the comparative inefficiency of the Rohilkhand method of boiling second *rab* is to a great extent due to more inversion.

It will be observed from the statement in Table XXXVI that some of the figures for increase of invert sugar are negative, or, in other words, in some parts of the process there is (at least apparently) a reduction instead of an increase in the quantity of invert sugar. This is specially the case with the following:—

(*a*) For the Bhopal system, from I *rab* to I molasses—*i.e.*, for the following operations,—aerating I *rab*, cooling and crystallizing it, pugging and machining the *rab* and drying and bagging the I Sugar.

(*b*) For both the systems, from II *Rab* to II Molasses—this covers the following parts of the process, aerating II *Rab*, Cooling and Crystallizing it, pugging and machining the *rab* and drying and bagging the II Sugar.

This apparent decrease in the quantity of invert sugar may be due, *inter alia*, to the following reasons:—

(*a*) When the hot *rab* is cooled by the process of aeration, its purity increases and, in some cases the percentage of invert sugar decreases. As the "purity" throughout these tests is "polarization—gravity solids purity", it is apparent that a reduction in the quantity of invert sugar will result in an increase of the purity also.

An explanation of these changes appears to lie in the fact that decomposition of reducing sugars particularly fructose takes place at high temperatures in the presence of air.* As fructose is the levorotatory constituent of invert sugar, its decomposition produces an exaggerated effect on the polarisation. Samples of Bhopal first and second *rabs* were analysed before and after aeration to test this theory. The results of the analyses are given in Table XXXVII and appear to bear out the explanation given above.

TABLE XXXVII.

Analysis of Bhopal Process Rab before and after Aeration.

Particulars	Bhopal process. Before aeration	After aeration
First Rab—		
Brix	88·68	89·77
Sucrose	68·40	70·60
Purity	81·26	82·26
Invert Sugar	9·2	7·8
Second Rab—		
Brix	87·43	91·36
Sucrose	51·0	53·6
Purity	58·3	58·6
Invert Sugar	18·3	18·3

(*b*) In curing the *rab*, the centrifugal machine baskets are washed with water after the sugar has been discharged, the wash water being run to waste. The water contains appreciable quantities of molasses mixed with it, the invert sugar contained in which is lost.

(*c*) The finished sugars (of both grades) are of low quality and contain invert sugar. The exact amount of this was, however, not estimated and does not therefore appear in the Invert Sugar Account.

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* See "Cane Sugar" by Noel Deerr, page 499.

Considering the importance of a correct Invert Sugar Account as a method of control over the open pan process, a more detailed study is necessary. The time and staff available at Bilari were not adequate for this purpose.

Comparison with Indigenous Khandsaris. In order to ascertain if the analytical data obtained at Bilari were comparable with those for average indigenous khandsaris in the neighbourhood, samples of *Rab*, Sugar and Molasses were obtained from three khandsaris and analysed in the Bilari laboratory. The samples were taken at random and special care was taken to avoid selection. All the three Khandsaris work by the old-fashioned methods and their products cannot therefore be said to have derived any benefits from the improvements embodied in the Bhopal or any other similar process.

Comparing the figures for analyses given in Table XXXVIII with those for Bhopal and Rohilkhand processes given in Table XXXII, it is observed that on an average the former compare favourably with the latter. This is particularly the case with the polarisation and moisture content of both grades of sugar,—even of the Khanchi Sugar.

TABLE XXXVIII.

Analysis of Samples obtained from Khandsaris near Bilari.

Serial No.	Khandsari	Sample	Sucrose	Brix	Purity	Invert Sugar	Moisture
1	Ram Ratan Jain, Bilari.	I Rab (only surface crust).	77·20	95·16	81·13	7·46	..
2	Ditto	I Molasses	43·00	81·85	52·53	16·69	..
3	Ditto	I Sugar	97·40	..	..	..	0·30
4	Jaitpur Farm	I Rab	77·60	91·89	84·45	5·05	..
5	Ditto	II Rab	41·40	93·57	44·24	18·29	..
6	Ditto	I Molasses	48·00	78·57	61·09	12·80	..
7	Ditto	Final Molasses (fermenting smell).	28·00	81·97	34·16	20·21	..
8	Ditto	I Sugar	99·20	..	..	..	0·20
9	Ditto	II Sugar	94·80	..	..	..	0·60
10	Bichaula Farm	I Rab	71·20	90·61	78·58	9·60	..
11	Ditto	II Rab	61·40	93·13	65·93	15·36	..
12	Ditto	I Molasses (Centrifugal).	46·40	81·43	56·98	16·00	..
13	Ditto	I Molasses (*Khanchi* fermenting).	41·40	78·45	52·77	19·20	..
14	Ditto	I Molasses (bags fermenting).	41·80	77·48	53·95	18·28	..
15	Ditto	I Sugar (Centrifugal)	96·80	..	..	..	0·30
16	Ditto	II Sugar (Centrifugal)	95·60	..	..	..	0·20
17	Ditto	I Sugar (*Khanchi*)	96·40	..	..	..	0·40

Note. (i) All the above khandsaris are near Bilari. They work according to the common Rohilkhand process.

(ii) The samples were obtained and analysed during the third week of April 1931. The quality of cane and juice was similar to that at Bilari at this period.

Comparison with Indian Sugar Factories. Some analysis figures taken from the report of a Sulphitation factory of moderate efficiency are given in Table XXXIX and a sucrose account for the same factory will be found in Table XL. A comparison of the figures in these tables with the corresponding figures for the Bhopal and Rohilkhand processes is of interest as showing the difference in the quality of the material handled by the two and the higher efficiency obtained by the factory. The sucrose account (Table XL) shows that for every 100 parts of sucrose in juice, the factory recovers, in the form of the finished sugars, 86·79 parts as against 71·26 parts and 60·52 parts respectively recovered by the Bhopal and Rohilkhand processes.

TABLE XXXIX.

Analysis Figures.—Whole season's averages for a Sulphitation factory of moderate efficiency.

S. No.	Particulars	Analysis
1.	*Cane*—	
	(a) Sucrose	12·13
	(b) Fibre	15·00
2.	*Bagasse*—	
	(a) Sucrose	4·89
	(b) Moisture	50·66
3.	*Mixed Juice*—	
	Sucrose	12·12
	Brix	15·13
	Purity	80·10
4.	*Syrup*—	
	Sucrose	42·77
	Brix	50·65
	Purity	84·44
5.	*I Massecuite*—	
	Sucrose	76·84
	Brix	92·06
	Purity	83·46
6.	*II Massecuite*—	
	Sucrose	64·41
	Brix	95·76
	Purity	67·26
7.	*III Massecuite*—	
	Sucrose	57·16
	Brix	98·79
	Purity	57·86

TABLE XXXIX—*contd.*

Analysis figures.—Whole season's averages for a Sulphitation factory of moderate efficiency—contd.

8. *Final Molasses*—	
Sucrose	35·51
Brix	93·72
Purity	37·88
9. *I Sugar*—	
Sucrose	99·60
Moisture	0·04
10. *II Sugar*—	
Sucrose	98· 0
Moisture	0·15
11. *Press Cake*—	
Sucrose	3·26

TABLE XL.

Sucrose Account.—Whole season's average for a Sulphitation factory of moderate efficiency.

Particulars	Per 100 cane	Per 100 sucrose in cane	Per 100 sucrose in juice
A. *Sucrose Recovered*—			
In I and II Sugar	9·07	74·77	86·79
B. *Sucrose Lost*—			
1. In bagasse	1·68	13·85	—
2. In press cake	0·08	0·66	0·77
3. In final molasses	1·27	10·47	12·15
4. Loss undetermined	0·03	0·25	0·29
Total lost	3·06	25·23	13·21

Turning to the cane crushing efficiency, the factory, on account of the high fibre content of the cane which it had to deal with, extracted 86·20 per cent. juice employing 18·95 maceration, that is, the extraction of undiluted juice was only 67·25 per cent. as against about 64 per cent. at Bilari. If a cane of the kind used by the factory had been treated at Bilari, the extraction of juice as well as the recovery of sugar would have been considerably reduced.

CHAPTER VI.

Special tests.

This report has so far dealt with the various aspects of the commercial test of the Bhopal and Rohilkhand processes. The processes could not be studied in detail from a scientific and technical point of view as, by reason of the tests having been primarily intended to be run on commercial lines, neither the staff nor the equipment provided was adequate for such scientific study. In spite of these limitations an attempt was made to collect as much data as possible and to study in more detail, by means of special tests, some of the important parts of the processes.

The special tests, the results of which are discussed in this chapter, covered the following subjects:—

(*a*) Normal temperature of liquid in the pans,

(*b*) Brix and acidity of liquid in the pans,

(*c*) Hydrogen ion concentration of juice in the pans,

(*d*) Analysis of flue gases of the *bels*.

(*e*) Furnace and flue temperatures of the *bels*,

(*f*) Heating surfaces and furnace data of juice boiling *bels*.

(*g*) Heating surface of molasses boiling *bels*,

(*h*) Output and fuel value of bagasse,

(*i*) Fuel consumption test,

(*j*) Work done by individual pans of juice boiling *bels*,

(*k*) Work done by individual pans of molasses boiling *bels*,

(*l*) Comparative test of Bhopal and Rohilkhand molasses boiling *bels*,

(*m*) Comparison of losses in potting *rab* in Kalsis and tins.

Normal temperature of liquid in the pans.—The purpose of this test was to determine the temperature of the juice (or molasses) in each pan after the *bel* has attained normal working conditions and also the time taken in reaching this condition. The tests were made on the four *bels*,—that is, the juice and molasses boiling *bels* of the Bhopal and Rohilkhand processes. Each test extended over one complete working day, and, starting from the time when the fire was lighted, readings were taken every half hour. Throughout these tests the *bels* were allowed to work in the usual manner.

The results of the tests are noted in Table XLI. It will be observed that the Bhopal juice boiling *bel* reached normal working condition in 2 hours after the firing commenced, whereas the Rohilkhand *bel* took 2 hours 45 minutes. On the other hand, the Bhopal second boiling *bel* took 30 minutes as against 15 minutes in the case of the Rohilkhand *bel* to come to normal working.

Table XLI.

Temperature in pans at normal working of bel.

Bhopal 1st Boiling Bel			Rohilkhand 1st Boiling Bel			Bhopal Second Boiling Bel			Rohilkhand Second Boiling Bel		
No. of pan	Temperature °C.	Time taken to come to normal working	No. of pan	Temperature °C.	Time taken to come to normal working	No. of pan	Temperature °C.	Time taken to come to normal working	No. of pan	Temperature °C.	Time taken to come to normal working
Raw Juice . . .	25	..	Raw Juice	25	..	Raw Molasses.	32	..	Raw Molasses.	32	
1st Pan . . .	69	2 hours .	1st Pan .	69	2 hrs. 45 mts.	1st Pan .	57	30 mts. .	1st Pan .	41	15 minutes.
2nd „ . . .	77	..	2nd Pan .	82	..	2nd Pan .	92	..	2nd Pan .	106	..
3rd „ . . .	85	..	3rd Pan .	101	..	3rd Pan .	111	..	(Striking temp.)	110	..
4th „ . . .	91	..	4th Pan .	101	..	(Striking temp.)	111	..	..	..	..
5th „ . . .	99	..	5th Pan .	110·5	..	..	..	..	..	..	..
6th „ . . .	98	..	(Striking temp.)	111	..	..	..	..	..	..	..
7th „ . . .	100	..	..	..	..	..	..	..	..	..	..
8th „ . . .	100	..	..	..	..	..	..	..	..	..	..
9th „ . . .	102	..	..	..	..	..	..	..	..	..	..
10th „ . .	107	..	..	..	..	..	..	..	..	..	..
11th „ . . .	107	..	..	..	..	..	..	..	..	..	..
(Striking temp.) . .	111	..	..	..	..	..	..	..	..	..	..

TABLE XLII.

Brix and acidity in each pan.

BHOPAL 1ST BOILING BEL			ROHILKHAND 1ST BOILING BEL			BHOPAL SECOND BOILING BEL			ROHILKHAND SECOND BOILING BEL		
No. of Pan	Brix of material in pan	Acidity	No. of Pan	Brix of material in pan	Acidity	No. of Pan	Brix of material in pan	Acidity	No. of Pan	Brix of material in pan	Acidity
(Raw Juice) . .	20·45	28	(Raw Juice) .	20·45	28	(Raw Juice) .	78·1	61·0	(Raw Juice) .	78·1	61·0
1st Pan . .	24·25	31	1st Pan . .	28·28	45	1st Pan . .	80·16	69·2	1st Pan . .	65·1	91·3
2nd ,, . .	24·95	29·8	2nd ,, . .	30·72	42·8	2nd ,, . .	78·87	107·6	2nd ,, . .	77·3	128·2
3rd ,, . .	27·92	42·78	3rd ,, . .	43·64	35·7	3rd ,, . .	79·07	130·7	(Finished product.)	88·5	148·5
4th ,, . .	27·62	29·38	4th ,, . .	48·27	25·7	(Finished Product.)	89·6	146·1	..	..	..
5th ,, . .	26·72	29·5	5th ,, . .	89·40	60	..	..	..	..	..	..
6th ,, . .	24·92	23·88	(Finished Product.)	88·62	60	..	..	..	..	..	..
7th ,, . .	26·85	24·58	..	..	..	..	..	..	..	..	..
8th ,, . .	41·26	30·0	..	..	..	..	..	..	..	..	..
9th ,, . .	61·05	35·7	..	..	..	..	..	..	..	..	..
10th ,, . .	88·51	58·57	..	..	..	..	..	..	..	..	..
11th ,, . .	88·51	58·57	..	..	..	..	..	..	..	..	..
(Finished Product) .	89·62	60·0	..	..	..	..	..	..	..	..	..

Note.—The acidity is expressed in terms of the number of c. c's. of $\frac{N}{10}$ NaoH Solution required for neutralizing 100 c.cs of material in the pan, using phenolphthalein as indicator.

The initial temperature in the first pan of both the juice boiling *bels* is the same (69° C) as also the finishing temperature (111° C). The increase in temperature from pan to pan is much more rapid in the case of the Rohilkhand *bel*. This is due to the heating surfaces of the pans being correctly proportioned in the latter *bel*.

Of the two second boiling *bels*, the Rohilkhand *bel* is at a disadvantage as very little heating takes place in its first pan. In the Bhopal *bel*, the heat is well-distributed over the three pans, and the temperatures are therefore in proper gradation from pan to pan.

Brix and Acidity of Liquid in the pans. This test was conducted with the object the finding out how much concentration takes place in each pan and what is the increase in acidity. Samples were drawn from each pan, composited for the whole day and analysed. The results are shown in Table XLII.

Referring to the Bhopal juice boiling *bel*, the most noticeable point is that all the seven flat-bottomed pans put together do less evaporation than the first or Hauz pan alone of the Rohilkhand *bel*, as the brix of the juice in No. 7 Bhopal pan is 26·85° and in No. 1 pan of Rohilkhand bel 28·28°. This confirms what was observed in connection with the temperatures of the pans that the Bhopal *bel* is not correctly or scientifically designed.

The increase in acidity of juice from the first to the last pan in both *bels* is the same, but the average acidity in the first three pans of the Rohilkhand *bel* is higher than in the first seven pans of the Bhopal *bel*. A possible explanation of this may lie in the fact that very little evaporation takes place in these seven pans, whilst at the same time large proportions of clarifying agents are added which neutralise some of the acids.

In the case of the molasses boiling *bels*, the Bhopal *bel* again shows its superiority in that the progress of concentration is more uniform and the increase of acidity is kept in better check.

Hydrogen Ion Concentration of Juice in the pans. Closely connected with the increase in acidity as the evaporation progresses is the pH value of the juice in each pan of the *bel*. For determining the pH values a Hellige Comparator was used. For want of time the determination could not be made for the molasses boiling *bels*.

In the first experiment, the pH value of the juice in each pan was determined every hour from the beginning till it became constant, which took 4 hours. The results are shown in Table

XLIII. The Bhopal and Rohilkhand processes both show serious drop in pH towards the finishing end.

TABLE XLIII.

pH. Values of Juice in the bels at different stages of boiling.

Pan No.	pH. at Start.	p H. after 2 hours	pH. after 3 hours	pH. after 4 hours
		A. *Bhopal bel.*		
1	5·4	5·4	5·4	5·4
2	5·4	5·4	5·2	5·2
3	5·4	5·4	5·2	5·2
4	5·4	5·2	5·2	5·2
5	5·4	5·2	5·1	4·9
6	5·4	5·1	4·9	4·9
7	5·4	4·9	4·9	4·9
8	5·4	4·9	4·6	4·6
9	5·4	4·6	4·4	4·4
10	5·4	4·6	4·4	4·4
11	5·4	4·6	4·4	4·4
		B. *Rohilkhand bel.*		
1	5·4	5·4	5·4	5·4
2	5·4	5·2	5·2	5·2
3	5·4	5·2	4·8	4·8
4	5·4	4·8	4·6	4·6
5	5·4	4·6	4·4	4·4

In the second set of experiments, composite samples of juice were taken from each pan for the whole day (Mercuric chloride being used as preservative) and pH values were determined in these. The tests were conducted on five days, and the results are given in Table XLIV. They mostly agree with the figures in Table XLIII which they serve to confirm.

TABLE XLIV.

Values of composite samples of juice in the bels.

Pan No.	1st Test	2nd Test	3rd Test	4th Test	5th Test
Raw Juice	5·8	5·8	5·8	5·8	5·8
		A. *Bhopal bel.*			
1	6·0	5·6	5·6	5·8	5·6
2	5·8	5·6	5·6	5·8	5·2
3	5·8	5·2	5·2	5·6	5·2
4	5·6	5·2	5·0	5·6	5·2
5	5·6	5·0	5·0	5·6	5·2
6	5·6	5·0	5·0	5·2	5·2
7	5·6	4·8	5·0	5·2	5·0
8	4·8	4·8	4·4	5·2	4·8
9	4·4	4·4	4·4	4·8	4·4
10	4·4	4·4	4·4	4·4	4·4
11	4·4	4·4	4·4	4·4	4·4
Rab	4·4	4·4	4·4	4·4	4·4
		B. *Rohilkhand bel.*			
1	5·6	5·8	5·8	5·8	5·8
2	5·6	5·8	5·8	5·2	5·4
3	5·6	5·6	5·6	5·2	5·4
4	4·6	4·4	4·6	4·4	4·6
5	4·4	4·4	4·4	4·4	4·4
Rab	4·4	4·4	4·4	4·4	4·4

Analysis of flue gases of the bels. In order to determine the efficiency of combustion in the furnaces of the *bels* used for these experiments, the flue gases were sampled by means of a pipe let into the chimney near the base, and analysed using an Orsat apparatus. The results are given in Table XLV. The low CO_2 content and the high percentage of CO in the gases from all the four *bels* show that combustion is very imperfect and that only a small portion of the heat of the fuel is being utilised for evaporation purposes. The Bhopal and Rohilkhand juice boiling *bels* are equally bad in this respect, but the Rohilkhand molasses boiling *bel* is slightly better than the corresponding Bhopal *bel*.

TABLE XLV.

Analysis of flue gases from different bels.

Serial No.	Particulars	CO_2 Per cent.	CO Per cent.	O Per cent.	N Per cent.
1.	*Bhopal Juice boiling Bel*—				
	1st sample	13·2	1·4	3·8	81·6
	2nd ,,	12·2	1·6	4·4	81·8
	3rd ,,	10·6	3·9	6·6	79·5
	4th ,,	12·0	2·0	5·2	80·8
	Average	11·8	2·2	5·0	80·9
2.	*Rohilkhand Juice boiling Bel*—				
	1st sample	9·6	1·4	6·8	82·2
	2nd ,,	11·2	1·8	6·6	80·4
	3rd ,,	10·2	3·8	6·6	79·4
	4th ,,	14·0	1·6	4·6	79·8
	Average	11·2	2·1	6·1	80·4
3.	*Bhopal Molasses boiling Bel*	5·8	4·0	7·2	83·0
4.	*Rohilkhand Molasses boiling Bel*	8·8	2·6	7·2	81·4

Furnace and flue temperatures of the bels. The furnace and flue temperatures of the two juice boiling *bels* were determined by means of a pyrometer. The figures are given in Table XLVI. The temperatures of the gases of the two molasses boiling *bels* could not be determined for want of time. The furnace temperature of the Bhopal *bel* is 717° and that of the Rohilkhand *bel* 843°—a difference of 126°. From the point of view of the rate of evaporation, the temperature of combustion is of the greatest importance, because the higher the temperature of the gases, the higher will be the temperature difference between gases and the contents of the pans. As explained later on, the heat transmission (on which depends the rate of evaporation) increases with

the temperature difference. In a well designed boiler furnace for burning green bagasse, the furnace temperature is 1,100—1,200°C.

TABLE XLVI.

Furnace and flue temperatures of different bels.

Serial No.	Particulars	Temperature °C.
1.	*Bhopal Juice boiling Bel*—	
	(a) Furnace Temperature—	
	1st reading	760
	2nd ,,	690
	3rd ,,	700
	Average	717
	(b) Temperature of flue gas (at base of chimney)—	
	1st reading	450
	2nd ,,	450
	3rd ,,	450
	Average	450
	(c) Drop in temperature from furnace to chimney (average)	266
2.	*Rohilkhand Juice boiling Bel*—	
	(a) Furnace Temperature—	
	1st reading	850
	2nd ,,	850
	3rd ,,	830
	Average	843
	(b) Temperature of flue gases (at base of chimney)—	
	1st reading	350
	2nd ,,	350
	3rd ,,	350
	Average	350
	(c) Drop in temperature from furnace to chimney (average)	493
3.	Atmospheric temperature	28

(NOTE. Temperatures of gases of the molasses boiling *bels* could not be taken.)

The reasons for the low temperature of the *bel* furnaces are firstly that as there is no grate and the bagasse burns on the floor of the furnace, air cannot pass *through* the mass of burning bagasse, secondly, that the total quantity of air admitted into the combustion chamber is insufficient (as shown by the high percentage of carbon monoxide in the flue gases) and thirdly, that the design of the furnace is such that before all the combustible carbon in the furnace gases has had time to burn and generate the maximum amount of heat, the gases are brought into contact with the under

surface of the juice pans (placed directly above the combustion chamber), whereby their temperature is lowered and the carbon passes out unburnt with the waste gases.

Complete combustion, with the excess air kept at the minimum requisite for such combustion, ensures high furnace temperature. The benefits accruing from such improvement are firstly a considerable saving in fuel as more heat is generated by the same quantity of bagasse; secondly, an acceleration of the rate of evaporation, which reduces the time during which the juice remains in process and minimises inversion losses, and thirdly, with higher temperature of furnace gases the boiling capacity of the *bel* is considerably augmented, thus reducing the capital cost and working expenses for a *bel* of a given juice capacity. Compared with the importance of a correctly designed furnace which will ensure efficient combustion, the shape and size of the pans, which appear to have engrossed the attention of those who devised the Bhopal process, are unimportant details. It is not surprising, therefore, that the Bhopal furnace is so defective that it has a working temperature considerably lower than that of the Rohilkhand furnace.

The inefficiency of the Bhopal furnace as compared with that of the Rohilkhand type is shown in a much more marked degree when the temperature of waste gases is taken into consideration. The temperature of these for the Bhopal furnace is 450° C., giving a total drop of temperature from the furnace to the chimney of 266° whereas in the Rohilkhand *bel*, the waste gases are at 350° C. and the drop in temperature is 493°. This drop in temperature is a measure of the quantity of heat utilised in doing useful work,—that is, in heating and evaporating the juice. The figures for drop in temperature indicate that the Bhopal furnace has an efficiency in this respect of only about 55 per cent. of that of the Rohilkhand furnace. This fact was pointed out to the advocates of the Bhopal process, who offered the following explanation:—

> "This is explained by the fact that the plant specially constructed for the Bilari test contained one pan less than in the standard plant used at the Bhopal model factory, as it was thought originally that the plant will have to deal with only a little over 100 maunds of juice daily and the cost of pan may therefore be as well saved. Had that one pan been provided behind the last "Hauz" in the Bhopal plant at Bilari, the temperature of the flue gas would probably have been equal to if not lower than in the Rohilkhand one and the output of the *rab* would have increased proportionately too."

This explanation cannot be regarded as adequate. In the first place, the "Standard" *bel* used at Bhopal during the 1930 tests consisted of 8 pans and not of 12 pans as stated above unless the reference is to some other "Standard" *bel* brought out subsequently. The important point, however, is that the addition of one pan, as suggested, cannot bring about a fall in temperature

of 100° C, because the available heating surface through which this heat will have to pass into the juice will be entirely insufficient for the purpose, assuming that the additional pan will be of approximately the same dimensions as those in use. The real cause of the inefficiency of the Bhopal furnace lies in the incorrect proportioning of the dimensions of consecutive pans forming the *bel*. In a subsequent paragraph, particulars are given of the exposed heating surface of each pan of the two *bels*. From a comparison of these it will be observed that the sizes and setting of the pans in the Rohilkhand *bel* are so arranged that the pans farther away from the furnace have larger exposed heating surfaces. In this way, as the temperature of the gases falls during their passage through the flue, the heating surfaces of the pans become bigger and the heating effect on each pan is thus correctly balanced. In the Bhopal *bel*, the sizes of consecutive pans have been fixed in exactly the reverse manner, as the pans farther away from the furnace have smaller heating surfaces, and in consequence of this only a small proportion of the heat contained in the gases is absorbed by the pans at the end of the *bel*.

Heating Surface and furnace data of juice boiling bels. Before proceeding to compare the merits of the Bhopal and Rohilkhand *bels* the factors on which the evaporating capacity and the thermal efficiency of a *bel* depends may first be briefly considered. The pan and furnace data relating to the Bhopal and Rohilkhand juice boiling *bels* have been brought together in Table XLVII.

A juice boiling *bel* is essentially a system for the transfer of heat, by conduction, from the hot products of combustion of the fuel to the juice contained in the pans. The extent to which it performs this function effectively and rapidly is a measure of the efficiency of the *bel*.

The number of heat units which can be transferred through a plate depends principally upon the difference in temperature of the gases on one side of the plate and of the liquid on the other side, and in a less degree upon the thickness of the plate. For small temperature differences, which are near to each other on the thermometric scale, the rate of heat transmission is proportional to the temperature difference. A different law, however, obtains when the temperature difference is very great, as is the case in ordinary juice boiling *bels*. Rankine* gives the following approximate formula for such conditions—

$$H = \frac{1}{C} \times (T_1 - T_2)^2$$

where H = the number of B. T. U.s of heat transferred per sq. ft. heating surface per hour—

T_1 and T_2 = Temperatures on the two sides of the plate in °F.
C = a factor lying between 160 and 200.

Bleychynden† subsequently showed as a result of an exhaustive series of experiments, that Rankine's empirical formula was sub-

* See "Manual of the Steam Engine and other Prime Movers" by Rankine.
† See "Transactions Institution of Naval Architects", 1894.

TABLE XLVII.

Pan and furnace data relating to Bhopal and Rohilkhand juice boiling bels.

Serial No.	Particulars	Total for the Bel		Bhopal Bel—Figures for each pan						
		Bhopal	Rohilkhand	I	II	III	IV	V	VI	VII
	A. Pan Data—									
1	Diameter of pan, inches	..	..	30	31	32	39	40	41	42
2	Depth of pan, inches	..	..	18	18	18	18	18	18	18
3	Full capacity, gallons	566·72	800·0	45·8	48·9	52·1	77·4	81·4	85·5	89·8
4	Exposed heating surface, sq. ft.	52·356	82·311	4·27	4·58	4·9	5·24	5·58	5·94	6·3
5	Exposed heating surface of each pan (taking H. S. of complete bel as 100).	100	100	8·1	8·8	9·4	10·0	10·6	11·4	12·0
6	Ratio—gallons full capacity per sq. ft. heating surface	10·8	9·7	10·7	10·6	10·6	14·7	14·5	14·3	14·2
7	Ratio—gallons full capacity per sq. ft. heating surface (taking figures for finishing pan as 100).	..	..	369	365	365	506	500	493	489
	B. Furnace Data—									
8	Temperature of flue gases °C (interpolated)	..	..	450	454	478	496	546	588	633
9	Temperature of pans °C (average for normal working)	..	..	69	77	85	91	99	98	100
10	Temperature difference °C	..	..	381	377	393	405	447	490	533

Serial No.	Particulars	Bhopal *Bel*—Figures for each pan				Rohilkhand *Bel*—Figures for each pan				
		VIII	IX	X	XI	I	II	III	IV	V
	A. Pan Data—									
1	Diameter of pan, inches	42	38	20	20	89	82	68	57	39
2	Depth of pan, inches	15	14	6·5	6·5	28	22	20	10·5	8·5
3	Full capacity, gallons	43·7	33·7	4·21	4·21	355·1	229·3	145·8	50·4	19·4
4	Exposed heating surface, sq. ft.	7·7	5	1·423	1·423	17·9	31·63	17·5	7·815	7·466
5	Exposed heating surface of each pan (taking H. S. of complete *bel* as 100).	14·7	9·6	2·7	2·7	21·7	38·4	21·3	9·5	9·1
6	Ratio—gallons full capacity per sq. ft. heating surface	5·6	6·74	2·9	2·9	19·8	7·2	8·3	6·4	2·5
7	Ratio—gallons full capacity per sq. ft. heating surface (taking figures for finishing pan as 100).	193	232	100	100	792	288	332	256	100
	B. Furnace Data—									
8	Temperature of flue gases °C (interpolated)	677	720	735	735	350	375	430	512	840
9	Temperature of pans °C (average of normal working)	100	102	107	107	69	82	101	103	108
10	Temperature difference °C	577	618	628	628	281	293	329	409	732

stantially correct and that the thickness of plate has only a small effect on the rate of heat transmission. Some of the results of his experiments are given in Table XLVIII.

TABLE XLVIII.

*Transmission of heat through plates.**

Difference of Temperature of the two sides of plate.	Heat transmitted per 1° difference per square foot per hour.	
°F	B. T. U.	
848	12·78	Plate 1·1875 inch thick.
1,013	15·26	,, ,,
1,278	20·9	,, ,,
626	10·89	Plate ·75 inch thick.
1,058	19·18	,, ,,
1,233	21·92	,, ,,
563	11·90	Plate ·5625 inch thick.
1,148	25·7	,, ,,
503	11·81	Plate ·25 inch thick.
723	16·55	,, ,,
893	20·65	,, ,,
738	16·46	Plate ·125 inch thick.
1,083	25·48	,, ,,

It is evident from these theoretical considerations that for a given temperature difference, the rate of evaporation in a pan of a *bel* will depend on the value of the ratio—

$$\frac{\text{Juice capacity of the pan.}}{\text{Heating surface of the pan.}}$$

If the value of this ratio is small, the rate of evaporation will be high. It will be observed from Table XLVII that the value for the Bhopal *bel* is 10·8 and for the Rohilkhand *bel* 9·7 which would indicate more rapid evaporation in the case of the latter. There is, however, an uncertain factor involved here which may alter these results,—namely, the actual quantity of juice carried by each *bel* under normal working conditions as distinct from the calculated full capacity of the pans. It was not found possible to obtain reliable figures for the former.

As the quantity of heat transferred varies as the square of temperature difference for a given reduction in the temperature difference (as, for instance, the fall from pan to pan of a *bel*), the above ratio must be reduced at a correspondingly increased rate, for the same quantity of heat to enter the several pans of a *bel*. The Bhopal *bel* is not correctly designed in this respect also as the sizes of the pans and their relative heating surfaces are arranged in an order exactly the reverse of that required by these essential conditions. This is clearly shown by the figures for the above ratio given in Table XLVII for each pan of the two *bels* and the corresponding figures for temperature difference

* See "Mechanical Engineering for Beginners" by R. S. McLaren, page 65.

It may be pointed out, however, that it is not obviously required to have the pans so designed that equal quantities of heat may be transmitted into all of them. In the pans where juice has simply to be heated, much less heat will be sufficient than in pans in which evaporation takes place. The exact quantities of these can be easily calculated from the specific heat of juice and latent heat of steam.

It is somewhat surprising that the Rohilkhand *bel*, which is after all only the villagers' device for concentrating the juice, should on scrutiny be found to conform to the elementary principles of thermal engineering, whereas the Bhopal *bel*, which is the outcome of nearly three decades of research work should be so lacking in these fundamentals. The explanation, however, is not far to seek. The Rohilkhand *bel* was not designed by an engineer, but it is, as it stands to-day, the product of generations of experience. During these long years it has doubtless undergone many changes and what a capable designer could have done at the beginning has been brought about, much more gradually, but none-the-less equally effectively, by a process of trial and error.

Heating Surfaces of Molasses boiling bels. The dimensions of pans as well as the heating surfaces and values of the ratio of pan capacity to heating surface are given in Table XLIX. The furnace temperatures could not be taken and hence the furnace data are not given.

TABLE XLIX.

Pan data relating to Bhopal and Rohilkhand Molasses boiling bels.

Serial No.	Particulars.	Total for the *bel*		Bhopal *bel* figures for each pan			Rohilkhand *bel* figures for each pan	
		Bhopal	Rohilkhand	I	II	III	I	II
1	Diameter of pan, inches	..	..	30	27	20	60	36
2	Depth of pan, inches	..	..	11·75	8·25	6·5	13·5	9·25
3	Full capacity, gallons	31·72	91·6	18	9·51	4·21	73·2	18·4
4	Exposed heating surface, sq. ft.	10·225	12·12	5·372	3·43	1·423	7·3	4·82
5	Ratio—Gallons full capacity per sq. ft. heating surface.	3·1	7·5	3·3	2·7	2·9	10·0	3·8

The general principles enunciated in connection with the juice boiling *bels* apply equally to the molasses *bels*. The design of the Bhopal *bel* for molasses boiling is more in conformity with these theoretical principles and the result of this is reflected in the better working of this *bel*.

Output and fuel value of bagasse. A simple test was made to determine the amount of bagasse fuel available when cane is crushed. A quantity of wet bagasse as coming from the mill was weighed and spread in the sun for drying in the usual way. After

two days the sun-dried bagasse was weighed. Moisture was determined in the original wet bagasse and also in the sun-dried bagasse. The results are given in Table L.

TABLE L.

Quantity of bagasse fuel available.

Particulars		
1. Juice extraction per 100 cane	65·2	per cent.
2. Wet bagasse per 100 cane	34·8	,,
3. Moisture per 100 wet bagasse	51·0	,,
4. Moisture per 100 sun-dried bagasse	3·9	,,
5. Sun-dried bagasse per 100 wet bagasse	52·6	,,
6. Scn-dried bagasse per 100 cane	18·30	,,
7. Ratio: weight of sun-dried bagasse to juice	1:3·56	,,

With 65·2 per cent. extraction of juice, 34·8 per cent. wet bagasse (containing 51 per cent. moisture) was obtained. On drying in the sun for two days, a bagasse containing 3·9 per cent. moisture was left, the proportion of which was 18·3 per cent. on the weight of cane and 52·6 per cent. on the weight of the original wet bagasse. The ratio between the weight of sun-dried bagasse thus produced and the juice extracted was as 1:3·56.

Another sample of bagasse obtained from Co. 290 cane was analysed to determine its composition and calorific value. The following results were obtained:—

	Per cent.
Sucrose	8·42
Moisture	51·10
Total dry solids	44·10
Fibre (or solids insoluble in water)	35·00
Volatile matter	27·36
Fixed carbon	19·61
Ash	1·93
Calorific value (dried sample)	8,300 B. T. U

Fuel Consumption test. The subject of fuel consumption is of very great importance, specially in Rohilkhand where firewood is now too expensive to be used for supplementing the fuel supply, should the available bagasse prove to be insufficient for boiling the concomitant quantity of juice.

To test the fuel consumption of the two juice boiling *bels*, two tests were carried out. In the first one, conducted on 21st March 1931, equal quantities of juice (115·92 maunds) were given to each *bel* and the fuel consisting of sun-dried bagasse was supplied after weighment. In the second test conducted on the next day, both the *bels* were worked for approximately the same time (about 13 hours) and as much juice as each *bel* could boil was supplied to it, weighed quantities of sun-dried bagasse being again provided as fuel.

These tests were meant for two purposes,—firstly, for determining the maximum juice boiling capacities of the two *bels* and secondly, for finding out their minimum fuel consumption. Data relating to the former are given in Table XIV on page 45 and the results have already been discussed in Chapter III. It is only the second aspect, namely, the determination of the minimum fuel consumption, which will be considered here. The data relating to this are given in Table LI.

TABLE LI.

Test for determining the minimum fuel consumptic of juice boiling bels.

	Bhopal	Rohilkhand
A. *First test on 21st March 1931—*		
(a) Juice boiled, maunds	115·92	115·92
(b) Time taken for boiling, hours . .	10·83	8·45
(c) Sun-dried bagasse burnt, maunds .	30·70	33·96
(d) Heating surface of *bel*, sq. ft. . .	52·356	82·311
(e) Juice boiled per maund, bagasse maunds	3·77	3·41
(f) Juice boiled per maund bagasse, per sq. ft. heating surface . . .	0·072	0·041
(g) Bagasse burnt per hour, maunds .	2·83	3·07
(h) Bagasse burnt per hour maunds per sq. ft. heating surface . . .	0·054	0·037
B. *Second test on 22nd March 1931—*		
(a) Juice boiled, maunds	131·10	178·42
(b) Time taken for boiling, hours . .	13·16	13·00
(c) Sun-dried bagasse burnt, maunds .	36·99	44·90
(d) Heating surface of *bel*, sq. ft. . .	52·356	82·311
(e) Juice boiled per maund bagasse, maunds	3·54	3·97
(f) Juice boiled per maund bagasse, per sq. ft. heating surface . . .	0·067	0·048
(g) Bagasse burnt per hour, maunds .	2·81	3·45
(h) Bagasse burnt per hour maunds per sq. ft. heating surface . . .	0·053	0·042
C. *Average for the season—*		
(a) Juice boiled, maunds	3788·29	5031·01
(b) Sun-dried bagasse (containing 4 per cent. moisture) available, maunds	1090·4	1421·2
(c) Ratio. Juice to sun-dried bagasse .	3·48	3·54

(NOTE. See remarks in Table XIII, page 44, and Table XIV, page 45, regarding the conditions under which these tests were conducted. Analysis of juice and *rab* are also given in Table XXXII.)

Before proceeding to discuss the results of the fuel test, it is necessary to consider a few preliminary points. The first one of these is that the tests were carried out towards the end of the crushing

season when the juice was of high density (see analyses given in Table XIV). The brix of the juice on the two days of the test was 19·17 and 19·35 as compared with 19·08, average for the season. As a result of this difference in brix, less fuel will be required to boil 100 maunds of juice under the test conditions than if the juice had a density corresponding to the average brix for the season.

The second point to be noted is that the *bels* were not worked, during the fuel tests, under normal working conditions as on other days of the season. This is obvious from a comparison of the figures for the quantity of juice boiled in each *bel* per hour and for the number of working hours per day, during the fuel tests, with the corresponding averages for the whole season, which are given below:—

	Bhopal	Rohilkhand
	Mds.	Mds.
A. *Juice boiled per hour*—		
(*a*) During 1st test	10·70	13·70
(*b*) During 2nd test	9·96	13·73
(*c*) Average for the season	8·76	10·97
	Hours	Hours
B. *Working hours of bel per day*—		
(*a*) During 1st test	10·83	8·45
(*b*) During 2nd test	13·16	13·00
(*c*) Average for the season	11·67	12·74

The results of the fuel tests are, therefore, of very little practical value. They only show what the minimum fuel consumption under ideal conditions can be,—when the juice is of high density and the *bels* are being run at their best. It is entirely incorrect therefore to say that because the available bagasse was found sufficient during the tests to boil the equivalent quantity of juice extracted from the cane, therefore the *bel* will, under actual normal working conditions, need no extra fuel. This is confirmed by the fact that large quantities of additional fuel purchased from outside had to be used during the season at Bilari.

The correct method of conducting fuel tests would have been to have weighed daily the fuel supplied to each *bel*, if not for the whole season, at least for one or two weeks. This was, however, found impracticable as the cost of labour would have been prohibitive and also as there was not always sufficient stock of bagasse to permit of this, nor was a separate weighbridge available for weighing the bagasse.

Reverting to the results of the test, such as they are, a comparison may be made between the two *bels*. The weight of juice boiled per maund of bagasse burnt in the first test was 3·77 in the Bhopal *bel* and 3·41 in the Rohilkhand *bel*. These figures cannot, however, be compared, because the latter *bel* worked for only 8·45 hours as against 10·83 hours for the former. The fuel consumption in starting and finishing a *bel* is abnormal and hence

if the entire run is of a much shorter duration in one *bel* than in the other one, the former *bel* will be at a considerable disadvantage.

In the second test, both *bels* worked for approximately the same time and the quantity of juice boiled per maund of bagasse in the Bhopal and Rohilkhand *bels* was 3·54 maunds and 3·97 maunds respectively, showing that the latter *bel* has a better fuel consumption. This is what might have been expected from the data regarding furnace and flue temperatures and the ratios of heating surfaces and capacities of pans, which have already been discussed in detail.

It may be mentioned that during the second fuel test the arch supporting the Parchhas of the Bhopal *bel* cracked. This was due to a miscalculated attempt at forcing the capacity of the *bel* beyond what it was intended for. The accident, however, did not materially reduce the rate of burning bagasse, as the figure for bagasse burnt per hour was 2·83 maunds in the first test and 2·81 maunds in the second test. Even if the higher of the two figures for the Bhopal *bel* for juice boiled per maund of bagasse,—namely 3·77 maunds in the first test,—be taken, it is still lower than the figure of 3·97 maunds for the Rohilkhand *bel*, when the latter is worked for 13 hours, which is close to the average daily working figure for the season of 12·74 hours.

In Table LI the calculated figure for sun-dried bagasse (containing 4 per cent. moisture) available during the season is given, as also the ratio of juice to sun-dried bagasse for the two *bels*. The values of the latter ratio for the Bhopal and Rohilkhand *bels* are 3·48 and 3·54 respectively. According to the test figures of 3·77 and 3·97 maunds juice evaporated per maund of bagasse, the bagasse produced during the season should have been sufficient to boil all the juice. Actually this was not the case and large quantities of extra fuel had to be purchased. This confirms that the test figures for fuel consumption are not correct.

Allowing for the artificial conditions under which the fuel tests were carried out, the conclusions which can be drawn are—

(*a*) That the Rohilkhand *bel* is at an advantage as compared with the Bhopal *bel*, in fuel consumption, both *bels* being worked under ideal conditions. This is also confirmed by the data obtained regarding furnace and flue temperatures and the ratio of capacities of pans to their heating surfaces;

(*b*) That neither of the two *bels* is efficient enough in respect of fuel consumption to be able to do without additional fuel even for juice boiling; and

(*c*) That both processes require extra fuel for boiling molasses to II Rab.

These results indicate a serious handicap for the open pan system of sugar making, specially in view of the high cost of firewood.

Work done by individual pans of juice boiling bels. The object of these experiments was to determine the extent to which clarification, evaporation, inversion and increase in acidity take place in each pan of the Bhopal and Rohilkhand *bels.* The procedure adopted was to take samples of juice each time it was ladled from one pan to the next one and to composite these samples for the whole day. The samples from each pan were preserved separately in two portions, one for brix determination using formaldehyde as preservative and the other for sucrose and other determinations using mercuric chloride.

The results of the analyses are given in Table LII and the following conclusions based on these may be noted:—

TABLE LII.

Analysis of material in individual pans of juice boiling bels.

Particulars of pan	Temperature °C.	Analysis				
		Brix	Sucrose	Purity	Invert Sugar	Acidity
A. Bhopal Juice Boiling Bel.						
Raw Juice	25	20·45	16·56	86·63	1·22	28
I Pan—Hauz (flat bottomed)	69	24·25	19·16	79·01	1·75	31
II „ „ „	77	24·95	19·24	77·12	2·06	29·8
III „ „ „	85	27·92	22·03	78·89	1·94	42·78
IV „ Nikhar „	91	27·62	22·01	79·69	2·08	29·38
V „ „ „	99	26·72	21·01	78·65	2·36	29·5
VI „ „ „	98	24·92	19·81	79·48	2·26	23·88
VII „ „ „	100	26·85	21·45	79·90	2·25	24·58
VIII „ Khaula (round bottomed)	100	41·26	34·00	82·41	3·29	30·0
IX „ Manjha „	102	61·05	50·20	82·22	5·06	35·7
X „ Parchha „	107	88·51	68·40	77·28	9·16	58·57
XI „ „ „	107	88·51	68·40	77·28	9·16	58·57
Rab after aeration	..	89·62	70·60	78·78	7·85	60·0
B. Rohilkhand Juice Boiling Bel.						
Raw Juice	25	20·45	16·56	86·63	1·22	28
I Pan—Hauz	69	28·28	23·90	84·50	1·93	45
II „ —Nikhar	82	30·72	24·49	79·73	2·54	42·8
III „ —Khaula	101	43·64	35·0	80·20	3·40	35·7
IV „ —Phadka	101	48·27	39·0	80·80	5·18	25·7
V „ —Parchha	110·5	89·40	69·4	77·63	8·53	60·0
Rab after aeration	..	88·62	68·60	77·41	10·52	60·9

(*a*) There is a large drop in purity between the raw juice and the juice in the Hauz pans of both *bels*, the drop being specially large in the Bhopal *bel.* This is partly due to the addition of deula extract, which, until it

is heated to coagulation point and is removed by skimming, increases the brix and consequently lowers the purity. The principal reason for the drop in purity, however, appears to be inversion due to increase in acidity and to enzyme action, the temperature in these pans not being high enough to inhibit decomposing action of the enzymes.

The initial drop in purity is a serious handicap for both the processes. The entire process of clarification which follows does not even bring the purity of the juice to the level of that of the original juice. If therefore the initial drop in purity could be avoided or reduced, the subsequent clarification would produce a juice of higher purity. As the amount of available sugar depends on the purity of the clarified juice (as explained on page 78), the benefit from increasing the purity of the latter is obvious.

(*b*) The increase in invert sugar and acidity and the drop in purity (compared with that of the juice in the first Hauz pan) are comparatively small in both the *bels* till the juice has attained a brix of 45° to 50°. The latter is approximately the brix of the syrup coming from a multiple effect evaporator in a sugar factory. It should be possible therefore to devise a process in which juice may be concentrated to 50° brix in open pans and may then be sent for final concentration and graining in a vacuum pan. Such a combined process will entirely change the aspect of the indigenous industry.

(*c*) The major portion of the loss of sugar takes place in the parchhas of both the *bels*, as up to this point the purity goes on increasing. Using a vacuum pan as suggested above is one method of avoiding this loss. A cheaper method will be to use a shallow film evaporator, placed at a suitable point on the flue so that the temperature may not be so high as to cause local overheating and yet evaporation may proceed rapidly.

(*d*) There is an increase in purity and reduction of invert sugar after aeration of *rab* in the Bhopal process, whilst the reverse is the case in the Rohilkhand process. A chemical explanation of the changes which take place in the former case has already been suggested in Chapter V. The fall in purity and the increase of invert sugar in the latter case appear to be due to the caramelization which takes place in the fixed parchha of the Rohilkhand *bel*. The effect of this is that the final *rab* from the latter *bel* has a considerably lower purity than the *rab* from the Bhopal *bel*, and the yield of sugar is correspondingly reduced.

Work done by individual pans of Molasses boiling bels. Figures similar to those for the juice boiling *bels* discussed above are given for the two molasses boiling *bels* in Table LIII. Here also it is noticed that there is an initial drop of purity in the first pan and also that the purity rises on aeration. Similarly the purity of the final *rab* is lower in the Rohilkhand process and this combined with the lower brix, explains the low recovery of II Sugar by this process.

TABLE LIII.

Analysis of material in individual pans of molasses boiling bels.

Particulars of pan	Temperature °C	Analysis				
		Brix	Sucrose	Purity	Invert Sugar	Acidity
A. Bhopal Molasses Boiling Bel.						
Raw Molasses (diluted)	32	67·08	79·6	60·03	13·7	100
I Pan—Nikhar	57	82·50	48·4	58·6	16·55	98·73
II ,, —Nikhar	92	83·83	48·6	57·9	16·7	93·24
III ,, —Parchha	111	87·43	51·0	58·3	18·3	98·73
Rab after aeration	..	91·36	53·6	58·6	18·3	94·21
B. Rohilkhand Molasses Boiling Bel.						
Raw Molasses (diluted)	32	67·08	79·6	60·03	13·7	100
I Pan—Nikhar	41	72·69	42·4	58·3	15·36	81·28
II ,, —Parchha	106	85·49	49·4	57·7	19·21	87·76
Rab after aeration	..	88·0	51·0	57·9	18·3	98·73

Comparative test of Bhopal and Rohilkhand Molasses boiling bels. The object of this experiment was to ascertain how far the better results obtained from the Bhopal *bel* were due to the *bel* itself and how far to the skill of the workmen and the quality of the molasses boiled. For this purpose the two *bels* were worked simultaneously under the following conditions:—

(*a*) *1st test.* Molasses obtained on machining I *Rab* of the Bhopal process was diluted and distribution equally between the two molasses boiling *bels*. The workmen of each *bel* worked on their respective *bels*.

(*b*) *2nd test.* Molasses from I *Rab* of Rohilkhand process was similarly distributed for reboiling and the workmen continued working on their own *bels*.

(*c*) *3rd test.* Molasses from I *Rab* of Rohilkhand process was again distributed for re-boiling, but the workmen of the two *bels* were exchanged.

The yields of *rab* and sugar obtained in the three tests are noted in Table XLIV. In all the tests the production of *rab* per 100

molasses and of sugar per 100 *rab* are higher from the Bhopal *bel* than from the Rohilkhand *bel*. This indicates the superiority of the former *bel*.

Table LIV.

Comparative trials of Bhopal and Rohilkhand bels for Molasses boiling.

Particulars	Bhopal bel	Rohilkhand bel
1st Test. Molasses from Bhopal I *Rab* boiled in both *bels*. Workmen of each *bel* worked on their respective *bels*—		
1. Molasses boiled, maunds	6·39	6·39
2. *Rab* produced, maunds	4·74	4·54
3. Sugar produced, maunds	1·39	1·10
4. *Rab* per 100 molasses	74·18	71·05
5. Sugar per 100 *rab*	29·32	24·23
2nd Test. Molasses from Rohilkhand I *Rab* boiled in both *bels*. Workmen of each *bel* worked on their respective *bels*—		
1. Molasses boiled, maunds	12·27	12·27
2. *Rab* produced, maunds	9·32	8·80
3. Sugar produced, maunds	1·87	1·36
4. *Rab* per 100 molasses	76·12	71·88
5. Sugar per 100 *rab*	20·06	15·45
3rd Test. Molasses from Rohilkhand I *Rab* boiled in both *bels*. Workmen of the two *bels* were exchanged—		
1. Molasses boiled, maunds	8·68	8·68
2. *Rab* produced, maunds	7·23	6·88
3. Sugar produced, maunds	1·41	1·13
4. *Rab* per 100 molasses	83·28	79·26
5. Sugar per 100 *rab*	19·50	16·42

Comparing the production of sugar in the first and second tests, it is found to be higher in both the *bels* in the first test (in which Bhopal I Molasses was reboiled) than in the second test (in which Rohilkhand I Molasses was reboiled in both *bels*). This shows that the Bhopal I Molasses is better for reboiling than the Rohilkhand Molasses.

A comparison of the second and third tests shows that with the same raw material (that is Rohilkhand I Molasses), the workmen of the Rohilkhand *bel* produced a lower percentage of sugar on the Bhopal *bel* (19·50 per cent.) than on their own *bel* (20·06 per cent.), whereas the Bhopal workmen, when placed on the Rohilkhand *bel*, improved the percentage of sugar from 15·45 to 16·42 per 100 *rab*. This indicates that the Bhopal workmen are better trained.

It is clear, therefore, that in all the three respects, that is, efficiency of the *bel*, suitability of the molasses and skill of the workmen, the Bhopal method of making Second sugar is superior to the Rohilkhand process.

Comparison of losses in potting rab in kalsis and tins. In order to determine the losses which take place when *rab* is stored in kalsis (earthenware pots) and to compare these with the losses on storage in tins, an experiment was arranged in which one day's output of first *rab* from the Bhopal and Rohilkhand *bels* was weighed and filled partly into tins and partly into kalsis, the number of tins and kalsis used for the *rab* of each *bel* being kept approximately equal. After completion of cooling and crystallization, the *rab* was taken out of the containers, weighed and machined. The weight of *rab* left adhering to the containers was determined by difference and the amount of this was calculated as a percentage on the weight of *rab* originally potted. It was found that on an average 5·61 per cent. of the *rab* originally potted was left adhering to the kalsis and 2·54 per cent. to the tins, giving a difference in favour of tins of 3·07 per cent. Detailed figures are given in Table LV.

TABLE LV.

Tests for comparing losses in potting rab in kalsis and tins.

Particular	Kalsis	Tins
A. *Bhopal Process*		
1. Quality of *rab*	First	First
2. *Rab* stored, maunds	8·63	15·78
3. *Rab* machined, maunds	8·13	15·39
4. Loss of *rab*, maunds	0·50	0·39
5. Loss of *rab*, per 100 *rab* potted	5·79	2·47
B. *Rohilkhand Process*		
1. Quality of *rab*	First	First
2. *Rab* stored, maunds	10·80	21·20
3. *Rab* machined, maunds	10·21	20·65
4. Loss of *rab*, maunds	0·59	0·55
5. Loss of *rab*, per 100 *rab* potted	5·46	2·59

This experiment, which was carried out during the writer's absence, is inconclusive, as it was not conducted under normal conditions. As a rule, kalsis are broken when *rab* is taken out and it is then possible to remove the adhering *rab* more completely than was the case in this experiment. Moreover, it is usual to wash off with water the last traces of *rab* from the containers (tins or kalsis) and this also was not done in the present instance. The figure for loss is therefore unduly exaggerated.

It does not, however, need an experiment to demonstrate that losses in using kalsis are more than with tins, and it is for this reason that tins are being used so extensively wherever *rab* is

made for machining and not for selling. When a khandsari does not machine the *rab* himself and sells it to centrifugal owners, it is cheaper and more convenient to use kalsis as there is no trouble about returning or paying for them as would be the case with tins.

There is a common belief amongst rab makers that crystallization takes place better in kalsis than in tins. No tests were made to investigate this point, but it is likely that the belief is correct because the rate of cooling in a kalsi is slower than in tins (as a result of which the crystals formed are bigger and harder), the exposed surface at the top is also much smaller, thus reducing crust formation and, finally, as there is no local cooling or chilling where the *rab* comes in contact with the walls of the container the formation of fine and uneven grain at these places is avoided. It is possible, however, to secure all the advantages of kalsis, without the disadvantage of higher loss due to absorption and breakage, if wooden containers are used as crystallizers. Boxes of suitable size are convenient and cheap. The writer has seen wooden casks being used for this purpose. The *rab* is filled into the cask through the bunghole, and the cask is allowed to stand on end during the period of crystallization. When the *rab* is to be taken out, the iron band near the top is loosened, and the end of the cask removed. The *rab* can then be easily baled out or poured into a suitable mixer. If, before opening the cask, it is rolled for some time, the rab gets fairly well mixed.

After washing out the cask the end is refitted and the cask is ready for use again. An ordinary 45 gallon cask has the capacity of a dozen tins, costs only slightly more and lasts very much longer.

CHAPTER VII.

RECOMMENDATIONS.

The experiments described in this report were primarily intended to be commercial tests. The few technical investigations which were made had to be of such a nature that they did not interfere with the commercial work. From a scientific point of view, therefore, the experiments did nothing beyond touching the fringe of the subject, but even so, they were sufficient to give an indication of the problems involved, and to emphasize the almost complete absence of even the essential technical data. Although work on the improvement of the indigenous process has been carried on for years by several workers, it has not been conducted on scientific lines and no substantial progress has therefore been made. The principles involved in this process are just as much the principles of chemical engineering as in any major industry of a similar nature and the methods of research should therefore have been analogous.

The first and most essential recommendation that has to be made is that a research station for the scientific study of the indigenous process should be provided in the western part of the United Provinces, where the Khandsari industry has long been established. Without an institution of this type in which sustained work can be done for at least four or five years it will not be possible to obtain the technical data necessary for improving the plant and process on scientific lines.

The location suggested will also be convenient and central for the important cane belt of Northern India, comprising the Punjab on the one side and Bihar and the eastern districts of the United Provinces on the other. The research station should be staffed by qualified technicians and equipped with up-to-date instruments. It should be part of the functions of the station to test machines and processes employed in the indigenous industry and to report on them. In this way the public will be able to know, from an impartial authority, the comparative merits of different types of machines and processes and the manufacturers of machinery will also have an opportunity of getting their machines tested under local conditions.

Coming to details, some specific suggestions are made below regarding the lines on which improvement appears possible. It is hardly necessary to point out that, before the suggested modifications can be brought into general use, they should be tried out experimentally and amended in the light of the experience so gained. It is hoped, however, that the recommendations mad will assist machinery makers in studying more closely the requirements of the industry and will also give some indication to Khandsaris of the lines on which they can improve their methods.

Cane Crushing. (a) Single or Multiple Mills. The common practice is to use three-roller belt-driven mills. It is difficult to

obtain maximum extraction of juice from such mills and in attempting to force them to do more work than they are capable of doing, break-downs take place.

Five-roller mills, consisting of a two-roller crusher of the Krajewsky or Splitter type and an ordinary three-roller mill, have been placed on the market by one or two firms. Such mills naturally give a higher extraction and also increase the capacity. They have, however, not been taken up by the public to any very great extent so far.

The writer believes that a six-roller milling plant is preferable to a five-roller unit, provided the rollers of the first mill of the former are provided with Splitter type of coarse grooving. As compared with the five-roller mill, the six-roller type has the advantage of one more crushing and with the larger grooving suggested the splitting effect produced by the crusher in a five-roller unit is obtained to a better extent in a six-roller mill—thus increasing the capacity and efficiency of both. There is the additional advantage in a six-roller mill that if one of the mills breaks down the other one can continue to work (though at a reduced efficiency). From quotations obtained from some of the important manufacturers, it appears that the price of two three-roller mills (for marking up a six-roller plant) of the sizes commonly used in this country (*viz.*, $10'' \times 14''$ and $12'' \times 18''$ rollers) does not differ materially from that of a five-roller unit with rollers of the same size. If allowance is made for the increased capacity and efficiency, the six-roller plant will really work out cheaper.

The above remarks apply to mills of what may be called medium and large capacities, that is, for mills having over one ton cane per hour capacity. For smaller sizes vertical three-roller mills of the type driven by bullocks are more efficient than horizontal three-roller mills. For the same size of rollers the vertical mills are lighter and cheaper than horizontal mills. The power consumption per ton cane crushed per hour is much less in the former as the friction on the trash plate is absent. The power attachment, and reduction gearing are, however, important factors affecting the efficiency. A power driven vertical mill of this type, specially designed by the writer, is at present on order from abroad. The mill has a capacity of half a ton of cane per hour and is so compact that it can be mounted with the oil engine for driving it on a trolley, the total weight of the mill, engine and trolley being under two tons.

(*b*) *Roller details.* Some of the more important details in connection with the six-roller mill suggested above may be mentioned here. The grooving of the first mill should be half-inch pitch for rollers of $10'' \times 14''$ and $12'' \times 18''$ sizes, and somewhat bigger for larger sizes. It should be deep and intermeshing. There should be chevron grooves on the top and feed rollers. The trash plate should be suitably grooved on both sides to fit into the feed and discharge roller grooves. The second mill should have finer grooving, six to the inch, and intermeshing.

The peripheral speed of the rollers should be 15 to 18 feet per minute. A lower speed will give better extraction but will reduce the capacity.

(*c*) *Power required.* Most manufacturers of belt driven mills err on the side of quoting for engines of too small sizes. This makes the price of the plant appear lower but is in the end false economy. A mill with an engine of insufficient power can be worked only by either making the roller openings too big or giving a light feed of cane, and in both cases the capacity and efficiency suffer. For doing efficient work a three-roller mill requires half a horse power per maund of cane crushed per hour and a six-roller mill requires 30 to 40 per cent. more.

(*d*) *Flywheel and belt speed.* In large milling plants, such as are used in modern factories, the engine is directly coupled through a compound gearing, to the mill tandem, and a heavy flywheel is provided on the Engine Crank Shaft. The energy of the flywheel serves to equalize any sudden fluctuations due to uneven feed of the mills. In a small belt driven mill, the conditions are different. In this case the opportunities for variation in power required are much larger. Thus if four or five sticks of cane more are fed at any time or if several canes happen to be fed with their roots together, the mill may become overloaded to the extent of 15 to 20 per cent. In the absence of a flywheel either the engine stops when this happens or the belt slips, the mill coming to a stand still in either case.

This is a serious defect and a great deal of milling trouble is traceable to it. To remedy it, the first condition is to make the feed as uniform as possible. This is dealt with later on in connection with cane shoots. But to equalize the power, it is suggested that a flywheel, of sufficient size, should be fitted on the shaft carrying the belt pulley on the mill gearing. This is not likely to increase the cost by more than 8 or 10 per cent., and will greatly improve the working of the mill.

To prevent the slipping of belt, it is necessary to increase its speed or the width. The average cane mill used in this country has a belt speed of 800 to 900 feet per minute. This is much too slow, as belts are usually run in factories at speeds above 2,000 feet per minute. But to do so in a cane mill, a triple reduction gearing will be needed, which will considerably increase the cost. The only practical remedy, therefore, is to provide as wide belts as possible. For $10'' \times 14''$ and $12'' \times 18''$ mills, belts $5\frac{1}{2}$ inches and $6\frac{1}{2}$ inches wide are recommended.

(*e*) *Cane and Bagasse Shoots.* Bagasse carriers are provided in some mills, but these are usually unnecessary, a simple discharge shoot being all that is needed.

Cane feeding shoots are much more necessary—but are either not supplied, or if supplied, are too small to be of much use beyond supporting the cane. What is required is a fair sized wooden hopper which will hold enough cane for 10 to 15 minutes crush. With a hopper of such dimensions, the mill attendant has simply

to keep on sliding the cane down into the mill and a uniform feed can be maintained more easily. In most cases it will be cheaper if the makers of the cane mill supply only the iron parts for fitting the hopper and send out drawings and complete instructions for making the hopper at site.

(*f*) *Juice Pumps*. The use of juice pumps, apart from saving a great deal of labour, also ensures continuous feed of juice to the boiling pans and prevents accumulation of juice which gives rise to bacterial action. In spite of these advantages pumps are not commonly used with small power driven mills, the reason being their high cost. For a 10″ × 14″ mill (costing Rs. 1,425) one Maker quotes Rs. 280 for the pump, whereas another maker quotes Rs. 650 for the same size. The pumps are of the plunger type and are made of gunmetal.

Very much cheaper pumps of the semi-rotary wing type can be used for pumping juice, provided a fine strainer is used at the mill juice tank for removing all cush cush. Such pumps made of cast iron can be had for under Rs. 25 for dealing with juice from up to 100 maunds of cane per hour. If made of brass, the price will be somewhat higher, but will still be considerably below the price for the plunger type pumps referred to above. The semi-rotary pumps can be easily driven from the mill.

(*g*) *Disinfection of Mills*. In order to inhibit bacterial action it is necessary not only to keep the mill, juice tanks, pumps and piping scrupulously clean but also to disinfect them daily. For this purpose the use of electrolytic chlorine or a solution of bleaching powder is recommended.

Juice boiling. The Bhopal and Rohilkhand *bels* for juice boiling have been examined in detail in previous chapters and the following recommendations are made on the basis of the conclusions arrived at already:—

(*a*) The Bhopal and Rohilkhand *bels* both have been found to be inefficient in respect of fuel consumption and furnace temperature. To remedy these defects, an attempt should be made to fit a fire-grate with firing doors on the top and in front and ash door below the grate. Such grates can be fitted to both types of *bels*.

(*b*) Excepting for the removable parchhas, the Bhopal *bel* has not been found to possess any other advantage over the Rohilkhand *bel*. Hence a Rohilkhand *bel*, with two removable parchhas, is recommended in place of the Bhopal *bel*.

(*c*) The Hauz of the Rohilkhand *bel* is unnecessary specially where cane is crushed by the owner of the *bel*. Hence the Hauz pan should be eliminated. This will reduce the cost of the *bel* by about one-third, and will not lower the capacity or efficiency.

(*d*) An improved juice boiling *bel* has been designed by the writer on the basis of the above suggestions. Details

of this are shown in Drawing G. It consists of the usual Rohilkhand *bel* with two parchhas of small size placed between the Khaula and Phadka pans and a fire-grate fitted for burning bagasse. The Hauz pan has been omitted. The drawing shows the setting of the *bel* in brickwork. This, however, is not necessary, excepting for the front part of the furnace. If desired, the iron fittings of the furnace can also be simplified and cheapened.

Amongst the advantages which the proposed *bel* possesses are, firstly, that its pans are of the usual Rohilkhand type and can be easily made locally and, secondly, that being fitted with a fire-grate and improved type of furnace, it can burn partially moist bagasse, thus making the working of the *bel* more independent of weather conditions.

It is necessary to point out in connection with the improved *bel* that it has not been tested so far. It is possible that some modifications in the size and position of the fire-grate and in the shape and size of the combustion chamber and flues may become necessary. Pending a proper test the design should therefore not be taken as final.

(*c*) It is very probable that a simple type of plant, combining the open pan and vacuum pan processes, and employing liming and sulphitation for clarification can be devised which will be cheap and will turn out sugar of better quality than the average Khandsari sugar. It will be premature, however, to go into details of this here as a plant of this kind will have to be put up and tested first. This can be done if a Research Station is opened, as suggested in an earlier section.

Molasses boiling. For boiling Molasses to Second *Rab*, the Bhopal *bel* is recommended for the present. It should be possible, however, to improve on this without much difficulty by adopting a modification of the syrup evaporator commonly used in the United States. This will ensure much more rapid evaporation and higher fuel efficiency. It will also be almost automatic in operation.

Storage of rab. For this purpose wooden boxes or casks are recommended. If the former are used, they can be conveniently made in the form of truncated pyramids, with removable sliding bases. This will facilitate the discharging of rab after crystallization.

Centrifugalling. The arrangemnt of having a separate kerosene engine for each machine should be discarded. Belt driven machines, fitted with fast and loose pulleys and driven off a common countershaft, are simpler and cheaper in running cost. Where electric power at cheap rates is available, electrically driven machines may be found advantageous.

Sugar drying. Under the conditions obtaining in a Khandsari it is difficult to improve on the existing method of sugar drying even though it is admittedly wasteful.

Supplying complete plants. One of the difficulties in the way of those intending to take up sugar manufacture on a small scale is that there is no firm, either in India or abroad, which can tender for and supply complete plants of this type of different capacities. It is in fact easier to buy and instal complete plants for large sugar factories because machinery makers not only send out the plant complete in every respect, but also provide erection drawings and full instructions for erecting and operating. The small scale sugar maker needs such assistance and guidance much more as he is generally without any technical knowledge and the size of his business makes it impossible for him to employ any technical men.

From the machinery-makers' point of view, although individual installations for the indigenous system are much smaller in value and size than sugar factory plants, the volume of business which they represent in the aggregate is much larger. As pointed out already, the Khandsari industry takes up five times as much cane as all the sugar factories of India put together. Moreover, it is likely to expand much more rapidly than the factory industry if suitable machinery is available, because of the small amount of capital required.

If a Research Station, suggested in a previous paragraph, is established, it will be possible for the machinery makers to have their plants tested before actually placing them on the market.

Supply of trained workmen. A great deal of trouble with machinery and inefficient working is due to lack of men who understand how to erect and operate the few simple machines which a Khandsari uses. Much of the apparently higher efficiency of the Bhopal method during the Bilari experiments was due to the considerable experience which the workmen employed for the purpose possessed. Such men are, however, not easily available and unless the owner of a *bel* happens to know the work himself, the fate of his business usually depends on what type of man he happens to get for working the *bel*. There is need for some arrangement for training men for this industry. The training should not be given in a technical or agricultural school as the type of men who come out of these institutions will expect higher salaries and different working conditions than the industry can provide. A better arrangement will be to give grants to selected Khandsaris calculated on the basis of a fixed number of men to be trained during a given period. An instructor may be kept for going round the different places where men are under training and giving them the necessary theoretical instruction. The cost of training under this arrangement will be much less than by maintaining a regular class and the training will be of an essentially practical nature.

If the proposed research station is established, training of workmen can also be undertaken in it.

The following are suggested as subjects in which training should be imparted:—

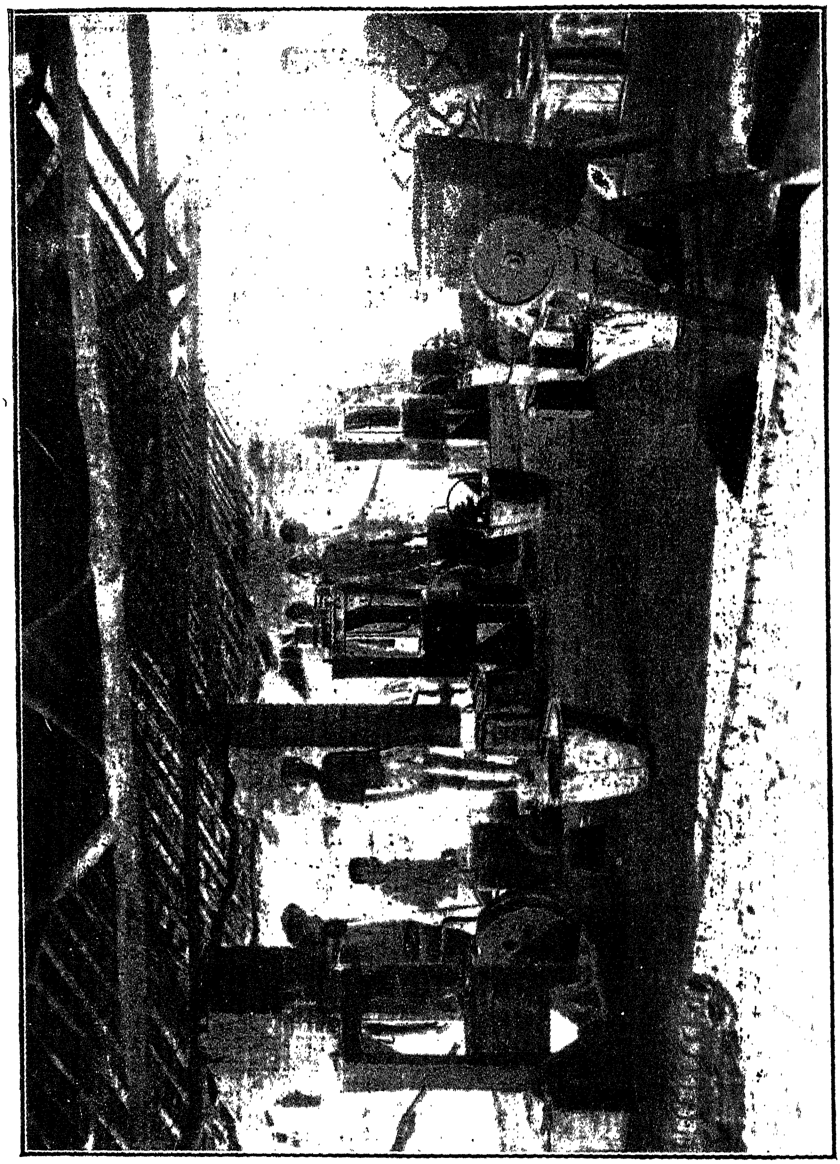
(*a*) Oil engines and electric motors—their erection, maintenance and repair.

(*b*) Cane mills—their erection, maintenance and repairs. Setting of rollers and trashplate.

(*c*) Juice and molasses *bels*—Method of building the furnace and operating the *bel*. Use of different clarifying agents.

(*d*) Centrifugal machines—their erection, maintenance and repair. Method of operating for different qualities and textures of *rab*.

PLATE V



General View of Centrifugal machines and Pugmills.

APPENDIX A.

USE OF THE CENTRIFUGAL.*

The centrifugal has gradually been gaining favour in Rohilkhand during the last 25 years, but up till now most people there have not been able entirely to control the quality of the sugar made with it, which is commonly termed "machine-sugar". Ordinarily the centrifuger puts the pugged *rab* (magma) into the centrifugal, after perhaps treating it with soda bi-carbonate to reduce viscosity, spins it with no special regard to speed or variations of speed, washes the sugar in the cage with warm or cold water or a decoction of the Ritha fruit (Sapindus Mukorassi or Soap-nut) and regards the haphazard result as the best that can be got. If the sugar mass has been over-washed, the resulting product is white but the recovery is low; if it has been underwashed, the recovery is higher, but the product is a more or less yellow sugar in which the crystals are coated with a thin film of molasses that spoils the keeping quality of the sugar by making it liable to fermentation. Incomplete elimination of molasses and consequently inferior quality of sugar is particularly common where the centrifuging is done on contract, as is often customary in Shahjahanpur. It is owing to such defects that machine-sugar is generally regarded by the trade as of a far lower grade than Khanchi sugar which usually receives more careful treatment from the manufacturer. On their side the owners of small sugar concerns attribute their want of success to the inefficiency of their centrifugals, whereas really it is mostly due to the ignorance of their centrifugers of the proper methods of manipulating the massecuites of varying qualities and different textures which they have to deal with in the usual course. There is not the slightest doubt that if each specimen of rab is rightly treated in the pugmill and in the centrifugal the whole of the resulting sugar should be superior in quality to the finest grade phul sugar of the bel-khanchi system, and should be infinitely better than the lower grade (adhauta and tarauncha) sugars of that system which are bleached with sewar.

The second great mistake of the Rohilkhand sugar-manufacturer lies in the method of re-boiling the molasses from the first sugar, to make a second massecuite (*rab*) for the production of second sugar, in which boiling the second massecuite never escapes charring. Whether the single or the double pan system is adopted, part of the boiling material is invariably caramelised in the finishing pan, the sugar crystals becoming charred by excessive and uncontrollable heat in the same way that corn is parched by the burning sand in the earthen vessel on the oven of the Indian grain-parcher. The brown colour which the sugar acquires from this charring, though not perceptible at the time to the naked eye, is so permanent that it is impossible to remove it either by treating the massecuite with soda bi-carbonate or any other alkali before machining it or by washing the sugar mass with water earth or a solution of chemical bleaching agent, while it is spinning in the centrifugal. Besides, the second massecuite ordinarily prepared in Rohilkhand is so viscous that it cannot be effectively cured in the centrifugal by the ordinary treatment of washing, however efficient or fast running the centrifugal may be. As a result, the local product is brown or dark coloured second sugar having a polarisation of 86 to 88 which sells at only a slightly higher price than gur, whereas it is possible under the Bhopal system to produce from the same basic material a second sugar which will polarise at 96 to 98 and is so good that when properly dried and sifted it can be mixed with the first sugar without reducing the market value of the latter.

In these days of keen competition with foreign sugars on the one hand and of high prices of cane and cane juice on the other hand, the salvation

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* Extract from the "Annual Report of the Department of Agriculture, Bhopal" for 1928-29, pages 21-28.

of the indigenous industry from gradual extinction lies in producing a second sugar of a quality at least as good as that of the first khand of Rohilkhand, and in obtaining as high a recovery of that as is possible by manipulative skill. At present the Rohilkhand manufacturer does not possess the requisite skill for either boiling or spinning the second massecuite, with the result that he cannot obtain the maximum profit from the raw material he employs. So long as this wastage continues in spite of the adoption of the centrifugal, there is little hope of the indigenous industry holding its own in open competition, however much the Indian product may be patronised by orthodox consumers. Here, too, the failure in this branch of the industry is commonly, though erroneously, attributed to the centrifugal, which is supposed to be unable to cure second rab: and the fact that it is really the second massecuite as ordinarily produced which is hopelessly bad is not understood for want of technical knowledge. The result is that many manufacturers, disappointed with the results obtained, give up trying to produce second sugar with the centrifugal and so lose what might be one-third of the weight of first sugar, to the great detriment of the indigenous industry.

It is therefore important in the interests of the Indian manufacturers to enunciate the principles which govern the highest attainable recovery of really good first and second sugars by the use of the centrifugal and to describe fully the practical methods by which such recovery can be secured from the different specimens of massecuite which may have to be dealt with by a sugar manufacturer, especially one who supplements the produce of his own *bel* by buying massecuites from cultivators under the "Khush Kharid" system. It cannot be expected, even where the Bhopal system of boiling is followed, that all massecuites prepared in the course of the boiling season will be uniformly good. Accidents will happen, juices of varying richness will have to be dealt with, stale canes will have to be manipulated and other disturbing factors will crop up. Thus in every season a manufacturer will meet with material for spinning which will be good, bad and indifferent. Accordingly the object of the following paragraphs is to enlighten the manufacturer as to the methods to be employed in order to get the best possible results from all kinds of rab in a centrifugal, and in all cases to produce sugar which will be better in quality than any that can be produced with similar basic material by the bel-khanchi system.

It has to be borne in mind that the centrifugal is merely a mechanical appliance, whose sole function is to separate molasses (the liquid portion of the rab) from crystals (the solid portion which is marketable cane-sugar). The degrees of elimination of the liquid will depend upon (*a*) the density of the liquid, (*b*) the ease of separation (on the application of centrifugal force) induced by sufficiently long storage of the *rab* during which the crystals naturally separate themselves from the molasses while still in the crystalliser vessels, and (*c*) the speed with which the centrifugal is capable of throwing out the molasses. Even the best centrifugal cannot be expected of itself to produce good white sugar in all cases. There is always far greater difficulty in producing good white sugar with the machine from close-boiled massecuites than from massecuites of thinner consistency, unless the former receive special treatment to bring about conditions which will make sufficient elimination of the liquid possible by the use of the centrifugal force available. The operation is still more difficult with second massecuites which, compared with first massecuites, are usually far more viscous even under the most careful method of boiling and contain much finer crystals as a rule. It is an art to deal properly with massecuites of different qualities in different types of centrifugals, and the centrifuger must be fully trained in it to obtain consistently good results.

Massecuites vary in texture, size of crystals, sucrose and glucose contents, viscosity and colour according to the stage of maturity of the cane, the richness of the juice, the time intervening between extraction and boiling, the care bestowed on defecation and clarification of the juice and on boiling the liquor, the rapidity of the latter concentration and the amount of

aeration given to the massecuites before storing it in crystallisers. Dealing with different varieties of cane in different localities at different stages of the season under conditions varying from field to field, it is impossible for the Khandsari to obtain *rab* of uniform quality or texture throughout the season, even when boilers are expert and have used their best skill. Some specimens will always be better and richer than others, while a number will be defective in one respect or another. Good and bad specimens require different treatment in the centrifugal in order to get the best returns out of them. There is no treatment which will apply equally well to all forms of *rab*. The general mistake, which is responsible for heavy avoidable losses, lies in the general practice of machining all forms of rab by one method, namely, merely spinning it in the centrifugal and washing the revolving massecuite with a spray of plain water or a decoction of ritha fruit, whereas it is essential that treatments should vary with the particular material.

Massecuites (rabs) can be distinguished under the following heads:—

(*a*) Loose (Dhili).

(*b*) Soft (Masin or Patli).

(*c*) Close-boiled-medium (Ausat).

(*d*) Close-boiled-hard (Karri).

Under "loose massecuite" come the specimens of *rab* boiled to the consistencies known as Kapasi, Sharbati and Mota-dora (for details see pages 128—130 of "The Indian Sugar Industry"). If the cane was rich, specimens of loose massecuite should shew well-formed strong crystals fairly large in size, which separate themselves from the molasses as a natural phenomenon in the course of storage, the molasses usually appearing at the top of the crystallisers. The molasses is usually thin and like the crystallised mass free from viscosity. But if such massecuites are stored too long, the crystallised mass below the molasses is apt to become very compact and difficult to dig out for pugging.

Under "soft massecuites" should be classed specimens which, owing mainly to the poverty of the juice and sometimes to slow boiling or too much "aeration" of the *rab*, contain very small crystals intimately associated with the molasses which refuses to separate during the period of storage. Such specimens are generally obtained when the cane is unripe, damaged, diseased or over-ripe, even though the cane may be naturally of a rich variety, or when the juice is extra-ordinarily acid. Occasionally a thick or thin layer of a frothy mass only partially crystallised (known as gobh) will be found on the surface of *rab* of this class. All second massecuites, even those made from the richest canes under the most skilful supervision, exhibit prominently the characteristic features of this type.

In the category "close-boiled-medium" should be included the different grades of the consistency known as Jaukhasi (barley-grained). This is the most desirable class of *rab* for machining purposes, and there are various grades of this class which may be denoted in order to indicate subtle distinctions in the texture, by the terms "thin Jaukhasi", and "thick-Jaukhasi". Thin Jaukhasi is only a shade thicker than mota dora, while thick Jaukhasi is a shade thinner than mohr jam. Medium Jaukhasi, which is midway between the two, is the ideal form for sugar-making. Massecuites of this category having little viscosity in them are easy of curing and generally yield crystals of the size most highly prized in the Indian market. The surface layer of the *rab* always sinks in the crystallizers in the case of these massecuites and the space vacated thereby is occupied by the liberated molasses which rises to the top.

Under "close-boiled-hard" should be classed the massecuites of the consistencies signified by the terms Mohr-Jam and Khunta-Thonk. These forms are the outcome generally of careless boiling or want of proper discretion in determining the final consistency, in other words, of over-boiling the *rab*. Specimens of this class are not uncommon in an Indian factory.

They are difficult to deal with in the centrifugal and require special treatment in machining. If the average Jaukhasi is kept too long in the crystallisers, it becomes as hard (owing to loss of moisture by evaporation) as *rab* of this type and should then undergo similar treatment.

The first duty of a centrifuger is to decide as to which of the various types described above the particular rab before him belongs and then to deal with it accordingly.

For loose rabs of type (*a*) no special treatment is needed, nor is very high speed of spinning necessary, when the rab is the first massecuite; about 1,500 revolutions per minute will be ample. The magma, after having been broken up in the pug mill or by hand, has only to be put into the centrifugal and the machine set spinning. If the centrifugal is one of 18″ diameter, the charge should vary from 56 to 60 lbs. The molasses will be found to drain off quickly. Towards the end of spinning the sugar in the cage should be sprayed with a ½ to ⅔ syringeful, *i.e.*, about 5 to 8 ounces, of plain warm water or preferably with a weak solution of sodium hydrosulphite of the same volume. The sugar when scraped out of the cage will be found to be a mass of fairly large crystals almost entirely free from traces of molasses. When crystals are large, they will be white but not brilliant. The larger the size of the crystals in the *rab*, the less will be the lustre. In order to impart brilliancy to the crystals, it will be necessary not only to expose the sugar mass to the bleaching action of the sun but to crush it gently with a wooden roller on a plank of wood placed over a carpet (pata) which is usually made of hemp fibre in Rohilkhand. Over the pata it is best to spread a piece of dark cloth so as to show the degree of whiteness distinctly to the observer from some little distance. The crushing should be done carefully so that the crystals may only be reduced in size but not smashed: otherwise the sugar will look mealy which is an undesirable feature from the customer's point of view. It generally takes 6 to 8 hours for the action of strong sunlight to complete the bleaching. Different varieties of cane seem to contain colouring matter in different quantities. In some the colouring matter is washed off easily and completely by moderate spraying in the centrifugal; in others more washing is found necessary. Speaking generally hereby all the so called "White canes", which have a green or yellow rind, yield white crystals in the centrifugal: whereas the crystals from red and purple canes are dull white or shew a slight tinge of pale pink or brown or yellow at the time of scraping the sugar from the cage, but when bleached in the sun and crushed become white. Sugar while still moist is seldom perfectly white. Evaporation of moisture improves the colour very remarkably. In the cage the top layer of about one-half to one inch in thickness is usually whiter than the inner layer which almost always contains more moisture, especially when big charges are dealt with. Rabs of type (*a*) are not ordinarily manufactured for commercial working, because large crystals are not wanted by the Indian market and because the yield of 1st sugar, whether such rab is treated in the centrifugal or the Khanchi, is low as a rule. In the centrifugal system it varies from 4 to 5 per cent. on the cane. However, *rabs* of this type are not rare in Indian factories, as a result of want of discretion on the part of the boiler in striking the last pan; and for that reason the type has been discussed at the above length. It would reduce the yield further if such rabs were subjected to the special treatments to be described presently.

For the sake of convenience soft *rabs* of type (*b*), which include second massecuites, will be noticed later on after the other forms of first massecuite have been fully discussed.

In the case of "close-boiled medium" forms of first massecuite of class (*c*), it is the various grades of the Jaukhasi ("barley-grained") *rab* that the manufacturer has generally to deal with at present and should continue to make his standard by instructing his boilers to confine themselves as far as possible to the production of this class of rab. If it is true to type and has been boiled with care, the molasses separated in the natural course within the crystallisers will be transparent, indicating production in the

centrifugal of sugar which may in the case of certain superior canes be snow white. If there is a thick dry crust on the top of the crystalliser as is sometimes the case, it should be removed by an iron scraper (khurpi) to be boiled later with the first molasses.

Before centrifuging, the rab should be broken up in the pug mill and the magma bleached by treating it with a strong solution of sodium hydrosulphite mixed with a little molasses obtained in previous working. From 10 to 15 grains of the chemical should be enough ordinarily to bleach 50 lbs. of rab: but should that quantity prove insufficient, as with the dark massecuites yielded by some of the purple canes, more hydrosulphite should be added gradually until the rab becomes yellow or orange yellow. The action of the chemical is almost instantaneous and is complete within a very short space of time. When working on a large scale, the *rab* should receive this treatment while it is being worked in the pug mill. Care should be taken not to use the chemical in excess as the gas evolved by its decomposition may irritate the respiratory organs of the workers. Rab so treated will hereafter be referred to in this narrative as "bleached magma".

While this treatment is in progress, some clear molasses, first or second, obtained in previous operations should be taken and treated with the hydrosulphite until it acquires a bright yellow or orange colour. It should then be diluted into a "syrup" with water to bring down its density to 72° or 73° Brix (the density of pure 1st molasses being about 77° Brix) and kept ready for use as explained below. Molasses so treated will be styled "sulphited molasses" in this narrative.

After being bleached, *i.e.*, sulphited, the magma should be charged into the cage of the centrifugal (50 to 56 lbs. being the usual charge) and the machine started to spin. For massecuites of this (*c*) class, a high speed centrifugal, such as Messrs. Broadbent and Sons' type 17-B which runs at 2,000 revolutions per minute, is the best and indeed is essential for the finest results. In three to four minutes after the start more than two-thirds of the molasses will have been drained from the cage. At this stage 7 to 8 lbs. of the sulphited molasses should be poured all at once into the cage, while it is running at full speed. This operation has been given the technical name of "syrup-wash". In a minute or two all this syrup will be thrown out. The sugar mass in the cage should then be washed with half a syringeful of a weak solution of stannous chloride (about one grain to the pint) and subsequently with an equal volume of plain water to wash out the traces of the chloride. Ordinarily about half a pint of the solution and an equal volume of plain water should be quite enough to wash a full charge. The standard syringe supplied by Messrs. Broadbent and Sons with their 18″ centrifugals holds one pint of water.

When completely cured, the sugar should be scraped out of the cage, bleached in the sun, crushed, sifted and bagged.

With this treatment, provided the rab was of normal strength, the quality of the resulting khand should be far superior to that of the best Phul of Rohilkhand.

If rab of class (*c*) becomes hard by long storage or other reason, as is sometimes the case with "thick jaukhasi", it should be treated as described below for class (*d*) massecuite.

The yield of first sugar will depend upon the quality and the colour desired. At present the Indian market does not demand large-sized crystals nor is much importance attached to special whiteness though whiter samples fetch a somewhat higher price. Indeed the Khal sugar of Rohilkhand, which is a mixture of the two grades phul and adhauta and is the main article of commerce, is not really white, whereas the average sugar made by the Bhopal process is white.

If the object is to make a sugar equal to or a little better than Khal in crystals and colour, the Bhopal process will, if the cane used is rich and the extraction of the juice fairly high (about 66 per cent. or so), give from rabs of class (*c*) a recovery of between 6 and 7 per cent. of first and shout

2 per cent. of second sugar, making a total 8 to 9 per cent. on cane (as compared with the 4 to 5 per cent. now obtained by Khandsaris in Rohilkhand), because in that case it will not be necessary to employ the sulphitation treatments described above or to wash the sugar mass thoroughly with water. Even a 10 per cent. recovery with rich canes would not be impossible, if a tinge of colour were not objected to. But if the intention is to make first and second sugars with a much higher degree of whiteness, stronger crystals, better keeping qualities, a more agreeable flavour and suitable for consumption at table, then the treatments described must be followed and, allowing for variations in the type of cane, the stage of the season and the care in manipulating the materials, a total recovery of from 7 to over 8 per cent. may safely be reckoned upon at the present stage of our investigations. The best Coimbatore seedlings generally yield more than 7 and often over 8 per cent. provided that they have not been over manured and that the crushing mills used are efficient, while inferior canes whether thick or thin yield less, in proportion to their sucrose contents.

When production increases as a result of these new methods, the classes who now solely use white foreign sugars will, in spite of a real wish to help the indigenous industry, be reluctant to replace the foreign by the Indian-made article in their households, unless the Indian manufacturer will produce a whiter product than the present day Khand. Even the orthodox classes, too, will come to demand a sugar of a higher degree of whiteness. Moreover Khand possesses a molasses-like smell, which is so disagreeable to Indian taste that Khand is never used at table until it has been reboiled with milk, clarified and converted into the refined form of sugar known as bura, the refining operation involving trouble, expense and an appreciable loss of sugar.

These matters have been carefully studied here and the research has evolved the sulphitation of the rab and the subsequent syrup washing, as above described, which both bleach the sugar and so deodorise it that the Khand smell becomes imperceptible. Our methods will insure quality and quantity for first and second sugars alike; but, as already indicated, much will depend on the skill of the centrifuger and the speed of spinning, even with massecuite of the finest quality.

Massecuites of class (*d*) "close-boiled-hard" which include rabs of the mohr-jam and khunta-thonk consistencies are rather difficult to deal with in the centrifugal. They are not necessarily viscous but are always hard with minute crystals closely packed together in a very compact mass. With mere spinning and washing, the sugar from them when scraped from the cage of the centrifugal (called pachhni at that stage) is tinted or yellow compared with the much whiter pachhni from massecuites (*a*) and (*b*). Although exposure to the sun improves this colour, the standard degree of whiteness is never attained and the resulting sugar is hardly any better than the average Khal of Rohilkhand. The recovery of first sugar from such *rabs* is, however, very high as a rule, as much as 58 per cent. on the *rab* having been recorded. But the spinning takes a long time, which raises the cost of manufacture and tends to increase the wear and tear of the machine. Besides, if the speed of the centrifugal is high, the molasses sticks to the crystals so firmly that considerable washing is found necessary to liberate it: serious losses of first sugar follow: and yet the final product is far from satisfactory. If, on the other hand, the speed is lowered, the molasses drains off too slowly and the results are still worse. Special treatment of this type of rab is therefore essential.

In the first place care must be taken to break the rab so thoroughly in the pug mill as to leave no lumps in the magma. If unbroken lumps are left in it, the distribution of the rab in the cage is uneven, the machine begins to vibrate almost as soon as it starts spinning, and it is very difficult to steady it. It must always be borne in mind that even moderate oscillation of a centrifugal in spinning reduces the quality of the sugar considerably below the standard. To avoid that, the magma must be liquified artificially, so as to give the original molasses associated with the crystals in the magma

a chance of draining off more quickly than it would do otherwise, and to force the crystals to separate from one another to some extent.

For this purpose 7 to 8 lbs. of first and second molasses taken from the storage tank of the factory should be placed in a vessel, about one dram of soda bi-carbonate dissolved in an ounce of water should be poured into it, and the mixture should be stirred briskly until it becomes frothy from the escape of the carbonic acid gas formed by the action of the alkali on the natural acids in the molasses. This "carbonated molasses" should then be mixed very thoroughly with about 50 lbs. of the magma, which is the maximum charge of it for a 18″ centrifugal. When working on a commercial scale, this mixing should be carried out in the pug-mill instead of being done separately by hand for each charge. Then the magma so treated should as described for massecuites of class (*c*), be sulphited with sodium hydrosulphite and allowed to stand till the bleaching action of the hydrosulphite is complete; then it should be spun, syrup-washed, and lastly sprayed first with a solution of stannous chloride and afterwards with plain water. It may be necessary perhaps to give an extra washing with a quarter syringeful of water in completing the spinning.

Under this treatment the outer layer of the 1st sugar in the cage should certainly be quite white, while the inner layer of about a half or a quarter of an inch will not be equally white, owing to the moisture in it which could not be expelled fully because the rush of the air could not force its way through the sugar mass on account of the compactness of the minute sugar crystals in the outer layer. The sugar can also be "blued" with a final spray of ultramarine dissolved in water before the spinning is stopped. This bluing disguises the tinge in the sugar and used to be practised in Rohilkhand, but has been abandoned there because confectioners found that sweetmeats made from the sugar had a bluish tinge which their consumers objected to.

Soft massecuites of class (*b*), whether first or second, may be sub-divided into non-viscous and viscous, the crystals in both kinds being usually minute, but particularly in the viscous type. All second massecuites belong to this class, the degree of viscosity depending partly on the care taken to boil the molasses while quite fresh, but still more on the sucrose content of the first molasses and the purity of the juice with which the first massecuite was made. If the recovery of the first sugar has been from 5½ to 6 per cent. on the cane, the first molasses generally yields a fairly good second massecuite. There will be no difficulty in boiling the first molasses drawn from weak massecuites for production of second sugar, especially if they have been made from poor juices. A treatment of saturated lime water in boiling the first molasses reduces the viscosity quite appreciably, but any excess of it darkens the second rab which then yields a brownish sugar. A judicious use of lime water in limited quantities is desirable in view of the improvement which invariably follows from it.

First massecuites of the non-viscous type give no trouble in machining, nor is it ordinarily found necessary to spin them in small charges. Their main disadvantage is that in a high speed centrifugal the inner layer in the cage is often not quite so thoroughly cured as the outer one, especially if the charge is big, though when both the layers (the inner moister than the outer) are scraped out, mixed together and bleached by the sun, a sufficiently white product results. If a whiter material is desired, the revolving sugar mass must be syrup-washed with sulphited syrup having a density of not lower than 73° Brix, because a thinner syrup would perhaps leave its own moisture behind in the inner layer and, with it, its yellow colouring matter. Care should also be taken, when spraying the sugar with water or a solution of stannous chloride, to do so sparingly because otherwise excess of moisture, which could not be fully expelled owing to the compactness of the sugar mass, would give the same colour to the inner layer as occurs from washing the mass with syrup of a low density. If heavy charges of 50 lbs. and over do not yield the standard quality with any particular specimen of rab, smaller charges should be used.

SECOND SUGARS.

It has already been observed that the only hope of placing indigenous white sugar on the Indian market at competitive rates lies in the recovery of second sugar of good quality and white colour. As that can be done to the extent of 1¾ to 2 per cent. on weight of cane, by the methods here described, the importance of strictly following the details of the processes cannot be too strongly emphasised.

In dealing with second massecuites, which from certain canes will be dark and will often be viscous, it is always essential to treat them with "carbonated molasses" and then to "sulphite" the magma before spinning. If the soda bi-carbonate does not reduce the viscosity sufficiently, a solution of sodium hydrate (NaOH) may be used instead, followed by sulphiting the magma. The charge also should not exceed 45 lbs. in an 18″ centrifugal and 40 lbs. may be a safer limit. Also it is very important that the centrifugal should be one in which the speed can be regulated at will. A centrifugal designed only to run uniformly at 1,800 to 2,000 revolutions per minute from the beginning to the end of the spinning operation will not answer the purpose, because such a speed does not give the molasses a chance of liberating itself, and the crystals in revolving get so entangled with the molasses that even copious washings with alkaline solutions and "syrup-washing" prove almost futile. Messrs. Broadbent and Sons' type 12 "Handelox" centrifugal worked by mechanical power and their 14″ hand-power centrifugal are machines in which the speed can conveniently be controlled and can be relied upon to give excellent results with second sugar. Those who wish to make second sugar would be well advised either to have a battery of two machines one being of the "Handelox" type and the other developing a uniform speed of 1,800 to 2,000 revolutions per minute such as Messrs. Broadbent and Sons' type 17-B centrifugal in its present form, both machines to be worked by an oil or steam engine, or else to have one machine of type 17-B which has been fitted with a gearing to regulate the speed as wanted.

With second massecuites of the viscous type, the speed of the machine should rise gradually from about 600 to 1,200 revolutions per minute until the greater part of the sticky molasses has slowly been eliminated without causing the cage to oscillate. When about three-fourths of the molasses have drained off, the sugar mass in the cage should be syrup-washed with a sulphited syrup of about 73° Brix density or, if the rab was very viscous, with a syrup of still lower density. The speed should then (and not before) be raised to its maximum, which is as necessary at this stage in the production of second sugars as it is throughout in the centrifuging of first massecuite into first sugar. As with other sugars, the mass in the cage should be washed with a weak solution of stannous chloride or plain water and the rest of the usual processes described above should be followed. Without the above treatment, it is impossible to obtain second sugar of good polarisation or colour with any type of centrifugal. The centrifugal must be fully trained and shuld gain sufficient experience to be able to deal efficiently with the massecuites of different types before being allowed to work independently, otherwise the best results will not be obtained, especially in dealing with the weaker masseeuties of the types of second rab.

It is hoped that the system has now been made clear, and that the reader will also realise that sugar-making, even as a village industry, is an expert business, in which knowledge of theory must go hand in hand with experience and technical skill in all branches of the manufacture.

APPENDIX B.

System of Chemical control prescribed for experiments conducted at Bilari.

Chemical control in the sense adopted in a modern Sugar factory, has never been attempted in a small scale factory making sugar by the open pan process. It therefore became necessary to lay down complete instructions regarding this for the guidance of the chemists deputed for work at Bilari. These instructions are reproduced here, partly as they may prove of interest to those who may wish to adopt a simplified system of Chemical control, and partly to indicate the method by which the technical data contained in this report have been obtained. It is well known that analytical figures relating to sugar manufacturing operations vary according to the methods of sampling and analysis followed and it is therefore necessary to know exactly the methods followed in a particular factory before a valid comparison can be made with the figures of another factory.

It should also be pointed out that the methods selected for adoption were similar to those followed in the Indian Sugar factories. Extreme scientific accuracy was not aimed at as the staff and the laboratory equipment available were not adequate for the purpose. The aim rather was to employ rapid methods of analysis which were at the same time reasonably accurate. The number of samples was also curtailed and a system of compositing of samples was adopted which served to obtain a small number of samples which were representative of the entire quantity of material under examination.

The prescribed system of Chemical control may be described under the following sub-heads:—

(*a*) Determination of quantities,

(*b*) Sampling and Analysis,

(c) Laboratory records.

A note is given at the end indicating the differences between the methods of sampling and analysis adopted at Bhopal (1930) and Bilari (1931).

Determination of Quantities.

In what follows, a day is reckoned from 6 A.M. to 6 A.M. the following morning, and a week from 6 A.M. on Monday to 6 A.M. on the following Monday.

The following system is to be followed for determining quantities for chemical control:—

1. *Cane.* To be weighed on the one-ton weighing machine. By fitting a bamboo platform on the machine, about 25 maunds of cane can be weighed at a time (instead of 12—15 maunds at present). This will save time and reduce errors of weighment.

2. *Juice.* It is not necessary to weigh each tin of juice as is being done at present. This requires too much staff and one weighing machine is not sufficient for weighing cane and juice both.

Juice should be measured and the weight calculated (the daily determination of density being part of the routine analysis).

For measuring juice two vessels (one for each mill) having ⅓rd or ¼th the capacity of a Kerosene tin should be used. Large *lotas* or small *gagras* will be quite suitable for this purpose. The exact volume of each vessel should be accurately determined in the laboratory and checked once a week. The volume of both vessels should be the same. If two such vessels are not obtainable, their volumes can be made equal by drilling overflow holes near the top.

These vessels should be given to the men who take out juice from the mill tanks for filling tins. They should be instructed to fill each tin with the same number of measures of juice each time. The number of tins filled in this way and delivered to each *bel* should be noted separately.

3. *I Rab.* The total quantity turned out from each *bel* each day should be weighed and the average tare of tins deducted. The tins should be numbered serially for identification of each day's production. The serial numbers should be noted along with weight of rab.

4. *II Rab.* As for I *Rab.*

5. *Molasses for reboiling.*—This consists of the following:—

(*a*) Molasses obtained on curing I *Rab*, including dilute molasses produced when spraying the sugar with water.

(*b*) Dilute molasses of II *Rab*, produced when spraying the sugar with water. This should, as far as possible, be collected separately from the molasses proper, as it is of much higher purity.

(*c*) Washings of pugmills, and centrifugal baskets.

All the above material should be weighed together (no attempt being made to segregate the products of each day's rab) whilst issuing to each bel for reboiling. The average tare of tins should be deducted for finding the net weight reboiled in each bel each day.

6. *Final molasses.* This is obtained on curing the II *Rab.* Dilute molasses should, as far as possible, be kept separate. When a sufficient number of tins has been filled, they should be weighed and average tare deducted. No attempt should be made to weigh separately the molasses from each lot of II *Rab.*

7. *I Sugar.* To be weighed after drying and bagging as each day's sugar is sent to godown or is despatched. No attempt should be made to keep each lot separate.

8. *II Sugar.* As for I Sugar.

9. *Scum.* The total quantity taken out of all the pans should be weighed together.

10. *Fuel and Sundry stores.* A record should be kept of the fuel, lubricants, sajji, deula, bhindi, etc., used and the quantities consumed *each week* should be communicated to the chemist. The consumption should be allocated to the following heads:—

(*a*) *Cane Crushing.* This is common to the Bhopal *bel* and the Rohilkhand *bel*. An allowance should be made for the quantities used for pumping water and for work other than the running and maintenance of the cane crushing mills.

From the total weekly consumption of fuel, lubricants, etc., the consumption per 100 maunds of cane crushed should be determined. The proportion to be allocated to each bel can then be calculated from the known weight of juice supplied during the week and the average extraction of juice for the week.

(*b*) *Bhopal bel.* The actual quantities supplied each week.

(*c*) *Rohilkhand bel.* The actual quantities supplied each week.

Sampling and Analysis.

As far as possible, the methods of analysis described in "Uniform methods of chemical control", issued by the Sugar Technologists' Association of India, should be followed, so that the results may be comparable with those obtained in the Indian Sugar factories.

1. *Cane.* Not to be analysed. Sucrose and fibre to be calculated daily from the analyses of juice and bagasse and the figure for extraction of juice per cent. cane.

2. *Bagasse.*

(*a*) *Sampling.* One combined sample per day from the two mills is to be analysed. Sampling should be done in the forenoon (about

11 A.M.) and afternoon (about 3 P.M.) on alternate days. No special precautions should be taken for feeding the mills at the time of sampling.

One large basketful of bagasse should be taken from each mill. It should be mixed and sub-sampled several times, chopping up the prices each time. The final sample should be chopped up as finely as possible. In the absence of a chopping machine, a hand chopper should be used.

The sampling and chopping should be done quickly and in an unexposed place to minimize loss of moisture.

(b) *Analysis.* Percentage of sucrose and moisture should be determined and that of fibre calculated.

3. *Juice.*

(a) *Sampling.* One composite sample (combined for the two mills) to be analysed daily at about 2 P.M. The sample should be collected in two vessels one for brix determination using formaldehyde as preservative and the other for sucrose determination using lead acetate or mercuric chloride as preservative.

Samples are to be taken from the two mill juice tanks, every half hour, by means of a vessel of fixed capacity and poured into covered containers in which preservatives have been previously placed.

(b) *Analysis.* Percentages of sucrose, brix, purity and invert sugar are to be determined. The following figures are to be calculated daily:—

(*i*) Juice extracted per 100 cane.

(*ii*) Sucrose in juice per 100 sucrose in cane.

4. *I Rab.* To be done separately for Bhopal and Rohilkhand *bels.*

(a) *Sampling.* From each finishing panful of *rab*, a sample should be drawn and composited whole day. Such daily samples should be composited for each week and analysed once a week.

(b) *Analysis.* Percentages of sucrose, brix, purity and invert sugar are to be determined.

5. *II Rab.* Sampling and analysis to be done separately for Bhopal and Rohilkhand *bels* as for I *Rab*.

6. *Molasses for reboiling.* To be done separately for Bhopal and Rohilkhand *bels.*

(a) *Sampling.* One composite sample representative of the total material (*i.e.*, I *Rab* molasses including dilute molasses of I *Rab*, and dilute molasses of II *Rab*) to be reboiled should be collected each day and analysed same day. Samples may be drawn from pans. If necessary, mercuric chloride may be used as preservative.

(b) *Analysis.* Percentages of sucrose, brix, purity and invert sugar are to be determined.

7. *Final molasses.* To be done separately for Bhopal and Rohilkhand *bels.*

(a) *Sampling.* A small sample should be drawn from each tin of molasses which is to be sold. Should be composited for the whole week and analysed once a week.

(b) *Analysis.* Percentages of sucrose, brix, purity and invert sugar are to be determined.

8. *I Sugar.* To be done separately for Bhopal and Rohilkhand *bels.*

(a) *Sampling.* A small sample should be drawn from each bag of dried sugar before weighing and kept in a corked bottle. Should be composited for the whole week and analysed once a week.

(b) *Analysis.* Percentages of sucrose and moisture are to be determined.

9. *II Sugar.* Sampling and analysis to be done separately for Bhopal and Rohilkhand *bels* as for I Sugar.

10. *Scum.* To be done separately for Bhopal and Rohilkhand *bels.*

(*a*) *Sampling.* When the total quantity of scum for each day is weighed, samples from different places should be taken and mixed for analysis. One sample to be analysed daily.

(*b*) *Analysis.* Percentage of sucrose to be determined.

Abstract of scheme for analytical work.

Serial No.	Material	Number of samples	Determinations required					
			Sucrose	Brix	Purity	Invert sugar	Moisture	Fibre
1	Cane . .	None figures to be calculated.	×					×
2	Bagasse . .	One daily .	×				×	
3	Juice . .	Ditto .	×	×	×	×		
4	I Rab . .	One weekly for each bel.	×	×	×	×		
5	II Rab . .	Ditto .	×	×	×	×		
6	Molasses for re-boiling.	One daily for each bel.	×	×	×	×		
7	Final molasses .	One weekly for each bel.	×	×	×	×		
8	I Sugar . .	Ditto .	×				×	
9	II Sugar . .	Ditto .	×				×	
10	Scum . .	One daily for each bel.	×					

Laboratory Records.

The following registers are to be maintained by the Chemists:—

(1) General Log Book,

(2) Register of Plant and Process employed,

(3) Analysis Register,

(4) Register of Quantities,

(5) Register of working figures for Bhopal process.

(6) Register of working figures for Rohilkhand process.

Specimens of the forms to be used for these registers are given at the end. A few explanatory remarks on these are given below:—

1. *General Log Book* (Form 1). In this the date and time of starting and stopping all principal manufacturing operations (*e.g.*, cane crushing, boiling juice or molasses in each *bel*, curing each lot of *rab*) should be entered. Interruption of work due to any cause (*e.g.*, rain, want of fuel, accidents, etc.) should also be noted. The log book is intended to be a complete daily record, in chronological order, of the work of the factory.

2. *Register of Plant and Process employed* (A blank book should be used). In this should be entered a complete specification (with necessary sketches) of the plant and a detailed description of the process employed. Any changes made during the season should be noted, stating the dates on which they are made.

3. *Analysis Register* (Form 2). The daily or weekly analysis figures should be entered in this. Columns are provided (between those for each Sunday and

Monday) for weekly averages. The averages should be true and not arithmetical averages.

4. *Register of Quantities* (Form 3). Figures for weights of different articles are to be supplied to the laboratory daily excepting in the case of stores (items 14, 15 and 16) which are to be supplied weekly. The figures for "Record of time" (item 17) are to be obtained from the General Log Book. Weekly totals and averages should be entered as explained above.

5 and 6. *Registers of working figures for Bhopal and Rohilkhand Process* (Form 4). Two separate books are to be maintained so that there may be no risk of the figures for the two processes under test getting mixed up. The form is self-explanatory. Weekly totals and averages are to be entered as explained before.

FORM 1.

General Log Book.

Date	Time	Particulars

FORM 2.

Analysis Register.

Serial No.	Analysis	January 1931							February 1931										
		20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
1.	*Cane*—																		
	Sucrose																		
	Fibre																		
2.	*Bagasse*—																		
	Sucrose																		
	Moisture																		
3.	*Juice*—																		
	Sucrose																		
	Brix																		
	Purity																		
	Invert sugar																		
4.	*I Rab (Bhopal)*—																		
	Sucrose																		
	Brix																		
	Purity																		
	Invert sugar																		
5.	*I Rab (Rohilkhand)*—																		
	Sucrose																		
	Brix																		
	Purity																		
	Invert sugar																		

6. *II Rab (Bhopal)*—
   - Sucrose
   - Brix
   - Purity
   - Invert sugar

7. *II Rab (Rohilkhand)*—
   - Sucrose
   - Brix
   - Purity
   - Invert sugar

8. *Molasses for reboiling (Bhopal)*—
   - Sucrose
   - Brix
   - Purity
   - Invert sugar

9. *Molasses for reboiling (Rohilkhand)*—
   - Sucrose
   - Brix
   - Purity
   - Invert sugar

10. *Final molasses (Bhopal)*—
    - Sucrose
    - Brix
    - Purity
    - Invert sugar

11. *Final molasses (Rohilkhand)*—
    - Sucrose
    - Brix
    - Purity
    - Invert sugar

FORM 2—*contd.*

Analysis Register—contd.

Serial No.	Analysis	January 1931							February 1931										
		20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
12.	*I Sugar (Bhopal)*—																		
	Sucrose																		
	Moisture																		
13.	*I Sugar (Rohilkhand)*—																		
	Sucrose																		
	Moisture																		
14.	*II Sugar (Bhopal)*—																		
	Sucrose																		
	Moisture																		
15.	*II Sugar (Rohilkhand)*—																		
	Sucrose																		
	Moisture																		
16.	*Scum (Bhopal)*—																		
	Sucrose																		
17.	*Scum (Rohilkhand)*—																		
	Sucrose																		

FORM 3.

Register of Quantities.

Serial No	Particulars		January 1931							February 1931										
			20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
1.	Cane crushed	Mds.																		
2.	Juice extracted	,,																		
3.	Juice, percentage of cane	,,																		
4.	Sucrose in juice per 100 sucrose in cane	,,																		
5.	Bagasse, percentage of cane	,,																		
6.	Wet bagasse produced	Mds.																		
7.	Dry bagasse produced (calculated)	,,																		
8.	Juice boiled—																			
	(a) In Bhopal *bel*	Mds.																		
	(b) In Rohilkhand *bel*	,,																		
9.	I Rab produced—																			
	(a) From Bhopal *bel*	Mds.																		
	(b) From Rohilkhand *bel*	,,																		
10.	Molasses for reboiling issued—																			
	(a) To Bhopal *bel*	Mds.																		
	(b) To Rohilkhand *bel*	,,																		
11.	II Rab produced—																			
	(a) From Bhopal *bel*	Mds.																		
	(b) Rohilkhand *bel*	,,																		

FORM 3—*contd.*

Register of Quantities—contd.

Serial No.	Particulars		January 1931							February 1931										
			20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
12.	Final molasses produced—																			
	(*a*) From Bhopal *Rab* . . .	Mds.																		
	(*b*) From Rohilkhand *bel* . .	,,																		
13.	I Sugar bagged—																			
	(*a*) From Bhopal *Rab* . . .	Mds.																		
	(*b*) From Rohilkhand *Rab* . .	,,																		
14.	II Sugar bagged—																			
	(*a*) From Bhopal *Rab* . . .	Mds.																		
	(*b*) From Rohilkhand *Rab* . .	,,																		
15.	Scum produced—																			
	(*a*) From Bhopal *bel* . . .	Mds.																		
	(*b*) From Rohilkhand *bel* . .	,,																		
16.	Stores for cane crushing—																			
	(*a*) Coal	Mds.																		
	(*b*) Lubricants	Srs.																		
	(*c*)	.																		
	(*d*)	.																		
17.	Stores for Bhopal Process—																			
	(*a*) (*b*) (*c*) } Enter names as required																			

18. Stores for Rohilkhand Process—

(a)
(b) Enter names as required . . . .
(c)

19. Labour—

(a) Cane to juice . . . . . No.

(b) Juice to sugar (Bhopal process) . . „

(c) Juice to sugar (Rohilkhand process) „

20. Record of time—

(a) Massey mill worked . . Hours.

(b) Chatanooga mill worked . . „

(c) Bhopal *Bel* worked I *Rab* . „

(d) Bhopal *Bel* worked II *Rab* . „

(e) Rohilkhand *Bel* worked I *Rab* . „

(f) Rohilkhand *Bel* worked II *Rab* „

FORM 4.

Register of Working Figures.

Serial No.	Particulars		January 1931							February 1931										
			20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
1.	*Cane*—																			
	(a) Weight of cane	Mds.																		
	(b) Weight of sucrose in cane . .	,,																		
2.	*Juice*—																			
	(a) Weight of juice	Mds.																		
	(b) Weight of sucrose in juice . .	,,																		
	(c) Weight of Brix in juice . .	.																		
	(d) Weight of Invert sugar in juice .	,,																		
3.	*I Rab*—																			
	(a) Weight of I *Rab*	Mds.																		
	(b) Weight of sucrose in I *Rab* .	,,																		
	(c) Weight of Brix in I *Rab* . .	,,																		
	(d) Weight of Invert sugar in I *Rab*	,,																		
4.	*Losses in boiling I Rab*—																			
	(a) Loss of sucrose	Mds.																		
	(b) Loss of Brix	,,																		
	(c) Increase of Invert Sugar . .	,,																		
5.	*Molasses for reboiling*—																			
	(a) Weight of molasses for reboiling	Mds.																		
	(b) Weight of sucrose in molasses for reboiling	,,																		
	(c) Weight of Brix for reboiling .	,,																		
	(d) Weight of Invert Sugar for re- [illegible] . .	,,																		

6.	*Rab*—	
	(*a*) Weight of II *Rab* . . .	Mds.
	(*b*) Weight of sucrose in II *Rab* .	,,
	(*c*) Weight of Brix in II *Rab* .	,,
	(*d*) Weight of Invert Sugar in II *Rab*	,,
7.	*Losses in boiling II Rab*—	Mds.
	(*a*) Loss of sucrose	
	(*b*) Loss of Brix	,,
	(*c*) Increase of Invert Sugar . .	,,
8.	*Curing I Rab*—	Mds.
	(*a*) Weight of I *Rab* cured . .	
	(*b*) Weight of I Sugar produced .	,,
9.	*Curing II Rab*—	Mds.
	(*a*) Weight of II *Rab* cured . .	
	(*b*) Weight of II Sugar produced .	,,
10.	*Final molasses*—	Mds.
	(*a*) Weight of final molasses . .	
	(*b*) Weight of sucrose in final molasses	,,
	(*c*) Weight of Brix in final molasses	,,
	(*d*) Weight of Invert sugar in final molasses	,,
11.	*Scum*—	Mds.
	(*a*) Weight of scum	
	(*b*) Weight of sucrose in scum . .	,,
12.	*Weekly efficiency cane crushing*—	
	(*a*) Juice, percentage of cane	
	(*b*) Sucrose in juice, percentage of sucrose in cane . . .	

FORM 4—*contd.*

Register of Working Figures—contd.

Serial No.	Particulars	January 1931							February 1931										
		20	21	22	23	24	25	Week	26	27	28	29	30	31	1	Week	2	3	4
13.	*Weekly efficiency—Juice boiling—* (*a*) I *Rab*, percentage of cane . . (*b*) I *Rab*, percentage of juice . . (*c*) Sucrose in I *Rab*, percentage of sucrose in juice																		
14.	*Weekly efficiency—Molasses boiling—* (*a*) Weight of II *Rab*, percentage of weight of molasses reboiled . . (*b*) Sucrose in II *Rab*, percentage of sucrose in molasses reboiled . .																		
15.	*Weekly efficiency—I Sugar curing—* (*a*) I Sugar, percentage of I *Rab* . . (*b*) Sucrose in I Sugar, percentage of sucrose in I *Rab*																		
16.	*Weekly efficiency—II Sugar curing—* (*a*) II Sugar, percentage of II *Rab* . (*b*) Sucrose in II Sugar, percentage of sucrose in II *Rab*																		

Note regarding differences in the methods of sampling and analysing adopted at Bhopal (1930) and Bilari (1931).

Juice. At Bhopal samples were drawn from each tin of juice and one composite sample was analysed for sp. gr. sucrose and invert sugar. Sucrose was determined by Herzfelds method of double polarisation. At Bhopal canes were crushed by bullock mills in 3 or 4 hours time for small scale variety tests. No preservatives were used there for collection of the sample of juice.

At Bilari juice was collected once every half hour till 2 P.M. in two bottles containing preservatives, one formal and the other mercuric chloride. Sp. gr. was determined in the former and sucrose from Direct Reading and invert sugar in the latter. Invert sugar in both the places was determined by titration with Fehling's solution using starch potassium iodide as outside indicator.

Bagasse. No bagasse was analysed for sucrose or moisture at Bhopal. At Bilari the sucrose was determined by the Java method after sampling and chopping the bagasse. Moisture in bagasse was estimated in samples of 50 grms. of chopped bagasse.

Rabs and molasses Normal or half normal solutions of these were prepared and analysed exactly as juice. Sucrose was estimated by inversion at Bhopal and from the direct reading at Bilari.

At Bhopal the *rabs*, sugars and final molasses were separately analysed for each day's boiling of the juice but at Bilari they were composited and analysed weekly.

Dilute molasses were analysed the same day they were produced. At Bilari they were collected in vessels containing mercuric chloride and sometimes analysed next day.

Scum was analysed at Bhopal the very day it was produced and no preservative was used, while at Bilari it was collected in vessels containing $Hg. Cl_2$ and mixed every time the sample was collected and analysed next morning. In both places 26 grms. was made up to 100 c.c. clarified with basic lead acetate and polarised.

Rab samples were taken from Pugmill at Bhopal on the day of curing and not on the day of preparation as was done at Bilari.

Polarisation of Sugar. 13·024 grm. sugar was dissolved in water, clarified with a small quantity of basic lead acetate and polarised after filtration. This was done in the same at both the places.

At Bhopal all the solution of *rabs*, molasses, sugars, etc., were made with distilled water, while at Bilari distilled water was only used for making reagents and the dilutions were done with clean tube-well water.

At Bhopal juice was weighed, while at Bilari it was measured by volume in a jug having a overflow hole and its weight found out from the ap. gr. of the composite sample of juice collected for daily analysis.

MGIPC—S4—III-1-60—21-6-32—1,000.